To:
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Contract No. 955782
Modification No. 5

Final Supplemental Report

AN IMPROVED BATTERY STATE-OF-CHARGE INDICATOR

Date:

30 September 1984

"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the U.S. Department of Energy through an agreement with the National Aeronautics and Space Administration."

Gould Inc.
Gould Research Center
Electronic & Computer Systems Laboratory
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Rolling Meadows, IL 60008

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Prepared By:
Robert T. Calvert

Approved By:
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EXECUTIVE BRIEF

Contract No. 955782 was a research contract performed by the Gould Research Center for Jet Propulsion Laboratory, California Institute of Technology. It was sponsored by the U.S. Department of Energy through an agreement with the National Aeronautics and Space Administration. This final supplemental report addresses Modification No. 5 of said contract.

The primary objective of Modification No. 5 was to develop an improved battery state-of-charge indicator having an adaptive battery parameter algorithm which would compensate for aging batteries and varying environmental conditions. The scope of this effort was limited to software modifications and additions which would perform with the existing Battery Charger/State-of-Charge Indicator (BC/SCI) hardware. Primary emphasis was placed on providing a reasonable state-of-charge indication accuracy for both new and aging batteries. Therefore, the previous accuracy limits of +0, -10% for new batteries was relaxed to +0, -20%, but was extended to include both new and aged batteries. Secondary objectives of Modification No. 5 were to eliminate certain anomalous operational SCI readings (resulting from the way the SCI corrects the amp-hour reading following charge) and to make the existing and new software compatible with anticipated future hardware interfaces.

The battery State-of-Charge (SOC) algorithm implemented in the present BC/SCI software and hardware was retained. This algorithm is an adaptation of both the Martin and Shepherd equations for battery voltage under dc discharge conditions. The existing microprocessor hardware (based on the Motorola MC6809) has a limited amount of both volatile and non-volatile memory available for the additional programs and processing required to accomplish the objectives of Modification No. 5. This limitation would allow only nine complete data points of battery discharge profile to be recorded for battery parameter adaptation processing. The discharge monitor and SOC Fortran program (DISFOR) were modified to direct the collection of this data and to average the error in battery voltage prediction.

A primary battery parameter adaptive algorithm was developed and implemented in the Fortran software. An error minimization routine (Fortran subroutine

EMAFOR) changes battery capacity parameter Q2 to conform to a curve-fit using the data collected during the discharge monitor mode. This is done by minimizing an approximate integral-squared error (in the battery voltage prediction error divided by current) through successive perturbations of parameter Q2. The adaptor algorithm developed in the original contract was refined and simplified based on mathematical analysis and empirical studies of Gould's extensive library of battery discharge tests. It was found that adapting only the battery capacity parameter Q2 was sufficient to meet the accuracy requirements of Modification No. 5 as battery parameters R1 and R2 proved to have relatively little effect. To properly adapt using this error minimization algorithm the data recorded must represent a relatively smooth, constant power (or current) discharge. In many driving situations, however, the data collected will not be smooth. In this case the error minimization algorithm will not change the battery parameters.

An alternative incremental default algorithm was developed and implemented (Fortran subroutine IDAFOR) which is exercised after each equalization charge if the Error Minimization Algorithm has not changed the parameter Q2 since the last equalization charge. This default algorithm will decrement (or increment) the parameter Q2 based on a weighted average of the dynamic battery voltage prediction error (calculated during the discharge monitor) and the equilibrium battery voltage prediction error. The decrement (or increment) amounts are proportional to the amp-hours of cummulative discharge (driving) since the last equalization charge and are based on empirical aging studies. This algorithm will allow adaptation regardless of the nature of the discharge data.

Testing of the completed adaptive algorithms indicated that the accuracy of the SCI met the program goals. Although testing was confined to the laboratory, an extensive library of battery discharge data was employed representing a variety of batteries, aging conditions and recharge algorithms.

The software generated during this Modification No. 5, as well as the changes in the original software, were written in a manner to be compatible with the anticipated hardware and interface modifications. It must be pointed out that the accuracy of the SCI is predicated on the SCI microcomputer controlling the

elementary functions of the battery charger, i.e., turn-on, equalize request and turn-off. Furthermore, the battery charging algorithm should be similar to the one employed in the original BC/SCI.

Some recommendations are suggested for future high performance state-of-charge indicators. These include an SCI controlled electrical interface with the battery charger and an increase in the volatile memory capability to allow the retention of more discharge data records.

1. INTRODUCTION

This report discusses a follow-on program to develop and implement an improved battery State-of-Charge Indicator (SCI) for use in electrically powered vehicles. The work was performed by Gould Research Center under Contract No. 955782, Modification No. 5, for Jet Propulsion Laboratory, California Institute of Technology. It was sponsored by the U.S. Department of Energy through an agreement with the National Aeronautics and Space Administration. The original Contractor's Final Report (Reference 1) is referred to throughout this report.

The primary objective of this program was to develop an improved battery State-of-Charge Indicator having an adaptive battery parameter algorithm which would compensate for aging batteries and varying environmental conditions. Testing of the original SCI proved it to be accurate with new batteries at nominal temperatures. The scope of this effort was limited to the addition of new software and the modification, as needed, of the existing Battery Charger/State-of-Charge Indicator (BC/SCI) software. There were no hardware changes or additions made during Modification No. 5 of this Contract. Primary emphasis was placed on providing a minimum accuracy of State-of-Charge indication of +0, -20% or better, for both new and aging batteries. As a further objective, it was desired to eliminate anomalous operational SCI readings during the discharge mode near the end of discharge and anomalous SCI readings from a fully recharged battery wherein turning the system on and off results in a continuing decrement of the SCI level while the battery remains in a state of full charge.

The accuracy of the State-of-Charge Indicator (SCI) (developed in this original contract and as improved during this program) depends to a large degree on the coordination of the battery charger and the SCI. To date, this coordination has been controlled by the SCI microprocessor. If the battery charger is allowed to operate independently of the SCI, then the accuracy and calibration of the SCI may be adversely affected.

2. IMPROVED STATE-OF-CHARGE INDICATOR (SCI)

2.A. Description of System and Improvements

The State-of-Charge Indicator (SCI) developed under the original contract consists of a microcomputer system which is used to:

1) Acquire battery data.
2) Exercise the State-of-Charge software program.
3) Provide system control for the battery charger.

Figure 2.A.1 is a schematic block diagram of the improved State-of-Charge Indicator (SCI). This program, Modification No. 5, addresses modifications and additions to the software of the microcomputer. For a hardware description, refer to the original final report (Reference 1).

The SCI microcomputer control system has four distinct operational modes. These modes are: 1) discharge monitoring, 2) charging, 3) wake-up and 4) think (parameter adaptation).

The discharge monitoring mode is operational while the electric vehicle (EV) controller is on. In this mode, the battery parameters of voltage, current and temperature as well as time are measured. Using these parameters, battery state-of-charge is calculated and displayed on the display's bar graph. The state-of-charge definition employed is the ratio of the energy remaining in the battery if it were extracted at a 10kW rate to the energy (again if extracted at a 10kW rate) of a fully charged new battery. The state-of-charge is displayed in 10% increments. Contract Modification No. 5 has expanded the scope of the discharge monitoring mode to include the recording of discharge data and the averaging of the dynamic voltage prediction error (detailed in Section 2.B and 2.C) to allow for battery parameter adjustment to compensate for battery aging.

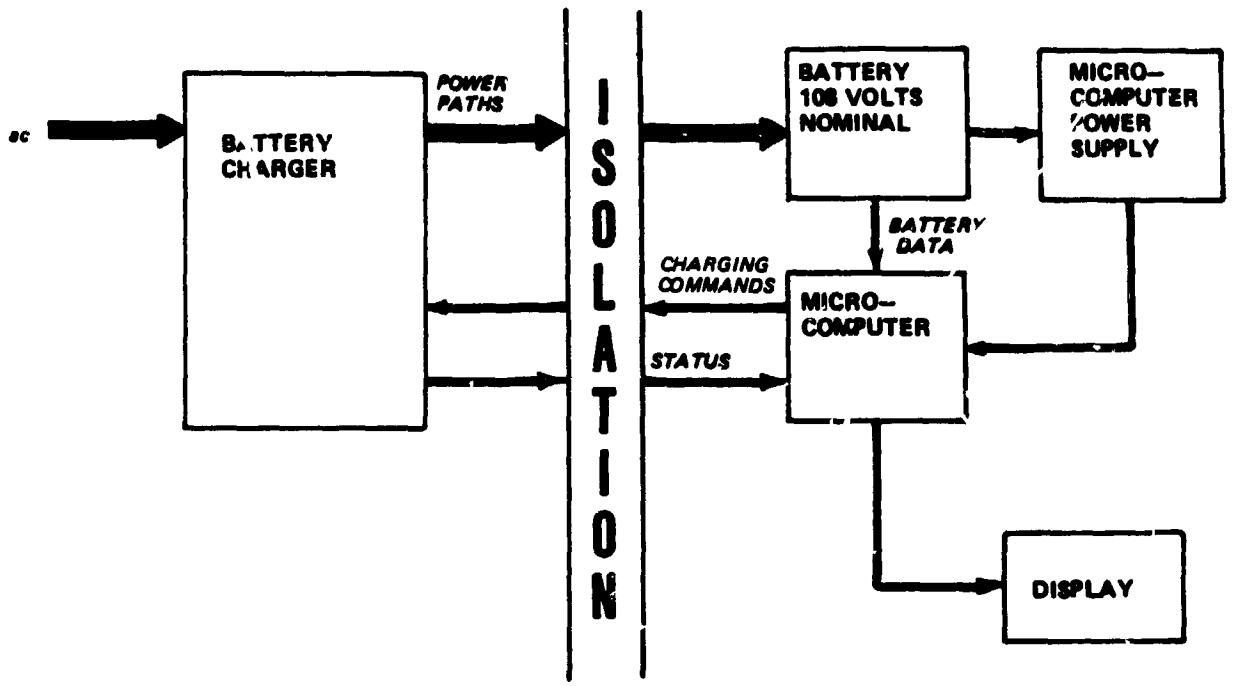


Figure 2.A.1 Improved state of charge indicator with battery charger interface.

The charging mode controls the battery charger. Under the original contract concept this included the charging profile and equalization charging profile. Program Modification No. 5 has included updating the average dynamic voltage prediction error and setting the flag for think mode operation (detailed in Section 2.B and 2.C).

The third mode, the wake-up mode, is one which is self-commanded by the microcomputer subsystem. This mode is exercised only after a battery discharge followed by two hours without recharging. During this mode, the value of the battery terminal voltage is measured and used as an estimate of the battery's equilibrium voltage. The measurement is used to assist in determining an adjustment to the amount of charge extracted from the battery. There have been no modifications or additions to this mode during Modification 5, however, the battery's equilibrium voltage prediction error is used in the think mode.

The fourth mode, the think mode, has been provided to give the SCI the capability of adjusting the battery model parameters as the battery changes its characteristics during its useful life. Prior to the efforts of Modification No. 5, this mode was not used. The program effort of Modification No. 5 has included the development of two algorithms to adapt, or adjust, the battery capacity parameter used in the SOC battery model. These are described in detail in Sections 2.B and 2.C.

2.B. State-of-Charge and Parameter Adaptor Algorithms

This section of the report reviews the model used to calculate the battery State-of-Charge (SOC) and addresses the two battery parameter adaptor algorithms implemented in the improved SCI. The development and motivation of the adaptor concepts are reviewed in detail. The improved error minimization adaptor algorithm is described and compared to the parameter adaptor developed but not implemented during the original contract. At the end of this section the incremental default adaptor algorithm is presented.

2.B.1 Phenomenological State-of-Charge Model

The phenomenological model may be thought of as a combination of both the Martin model (Reference 2) and the Shepherd model (Reference 3) for battery voltage under dc discharge conditions. A review of the Martin and Shepherd models is given in the original Final Report (Reference 1). Here we review the modifications made to them in order to arrive at the new model. Then, some of the issues involved in implementation of the phenomenological model on a microcomputer are addressed.

It has been found experimentally that one set of Shepherd equation coefficients (V0, V1, Q1, R1, R2, Q2) is not sufficient to accurately predict battery voltage for dc discharges over a wide range of currents and temperatures. However, if R1, R2 and Q2 are allowed to vary with both temperature, T, and current, I, then the resulting predicted voltage profiles can be fitted to actual data quite closely. In addition, if a filtered battery current, I_f, obeying the differential equation,

$$\tau \frac{dI_F}{dt} + I_F = I(t) \qquad (1)$$

is used in place of the actual current, I, then the predicted voltage is a reasonable approximation to the measured voltage, v, even under conditions of varying current. Thus, the phenomenological model predicts the battery voltage with the equation (Reference 1),

$$v(t) \cong V0 - \left(\frac{V1}{Q1}\right)Q(t) - R1(I_F,T)I_F(t) - \frac{R2(I_F,T)\ Q2\ (I_F,T)}{Q2\ (I_F,T) - Q(t)} \cdot I_F(t) \qquad (2)$$

where Q(t) is the net charge removed from a fully charged battery.

In order to implement this model to predict state-of-charge, an array of values for R1, R2 and Q2 at various discrete values of current and temperature are required. A microcomputer keeps track of the withdrawn charge, Q, and filtered current, I_F, during a discharge. At any time that the remaining capacity is desired, the processor begins an imaginary discharge, varying the current so as to keep the product v(t) * I(t) equal to the standard discharge power. Linear interpolation between the discrete values of temperature and current for which the battery data are stored is used to compute estimates of R1, R2, and Q2, so that battery voltage predictions can be made. The remaining energy is then the product of the standard power rate and the time (in the imaginary discharge) until the voltage falls below a specified cutoff level (~ 1.7V/cell).

Table 2.B.1 contains the array of Shepherd coefficients as functions of discharge current and battery temperatures. R1 and R2 are in milliohms per cell; Q2 is given in amp-hours.

Table 2.B.1.

Cell Parameters

CURRENT (A)	BATTERY TEMPERATURE 9C	20C	40C
20	R1 = 2.7293	R1 = 2.9568	R1 = 2.2395
	R2 = 0.5078	R2 = 0.3792	R2 = 0.2180
	Q2 = 125.8763	Q2 = 164.4615	Q2 = 188.8593
80	R1 = 1.8282	R1 = 1.7384	R1 = 1.3714
	R2 = 0.2137	R2 = 0.1732	R2 = 0.1794
	Q2 = 83.0000	Q2 = 109.4000	Q2 = 141.3512
130	R1 = 1.6844	R1 = 1.5260	R1 = 1.3090
	R2 = 0.1198	R2 = 0.1216	R2 = 0.1331
	Q2 = 69.3520	Q2 = 91.8800	Q2 = 121.0732
200	R1 = 1.6320	R1 = 1.2800	R1 = 1.2854
	R2 = 0.0940	R2 = 0.1600	R2 = 0.1195
	Q2 = 70.7200	Q2 = 84.8000	Q2 = 98.2439

These parameters were derived from constant current discharge experiments employing Gould PB-220 golf cart batteries. The voltage and the charge withdrawn were recorded during each discharge and compared to voltage curves predicted by the Shepherd equation to determine the best set of Shepherd coefficients for each experiment. The battery recharge profile employed during this testing was an equilibrium recharge profile with an overcharge of 20%. This was necessary to achieve repeatable test results for the battery under test.

2.B.2 Development of Battery Parameter Adaptor Concept

The accuracy of the SOC algorithm and of the SCI itself was tested by both Gould and JPL during, and after, the original contract. The battery SOC algorithm implemented in the BC/SCI previously is capable of the original goal of +0, -10% accuracy only when equipped with accurate battery parameters (Reference 1). The feasibility of tracking, or adapting, these battery parameters as the battery ages was demonstrated under laboratory conditions during the original contract, however, this capability was not included in the original BC/SCI software due to the excessive computer capacity required for its implementation. Modification No. 5 was thus undertaken to simplify the parameter adaption program to allow its implementation in the SCI.

2.B.2.a Originally Developed Parameter Adaptor

The battery parameter adaptor developed during the original contract was described in detail in the original Final Report, page 60 through page 69 (Reference 1). This adaptor will be referred to as the "Original Adaptor" throughout this report.

The accuracy of the phenomenological battery model is dependent on the accuracy of the Shepherd coefficients which characterize the battery performance over the range of temperature and current. Unfortunately, these parameters change as the battery ages. The parameter adaptation algorithm developed during the original contract attempted to modify the Shepherd coefficients to reduce the difference between the measured and predicted voltages occuring during the course of previous discharges. Conceptually, the parameter modification would occur following the completion of a complete discharge and charge cycle.

The original concept of parameter adaption requires the processing of some form of record for a complete discharge rather than making decisions based upon short sub-divisions of a discharge cycle. The major disadvantage of such an approach is the amount of data compression required to fit a complete discharge record in the available microcomputer dynamic memory, on the order of 100 bytes. This was one of the technical limitations that prevented the

original adaptor from being included in the original BC/SCI software.

The discharge summary was to be in the form of several separate records. Each record would describe the scheme's performance over a particular section of the discharge, during which the discharge operating point in (I,T) space, current and temperature, remained nominally within one zone. A record was to be kept only if the amount of time elapsed (and/or charge removed) during the corresponding section was above some minimum value. If a record was to be written, and insufficient space existed in memory to write the record, a means of evaluation of the record's "importance" was used to determine whether or not to delete an already-written record.

In order to adjust the battery parameters according to the data obtained in the records, the following procedure was to be used. First, the actual voltage profile during each section could be reconstructed by assuming that each section could be modelled as a constant-current, constant-temperature discharge, at the current, I_A, and temperature, T_A.

Thus, the predicted battery voltage would be

$$V_p^o = V0 - \left(\frac{V1}{Q1}\right)Q - R1^o I_A - \left[\frac{R2^o Q2^o}{Q2^o - Q}\right] I_A \qquad (3)$$

where $R1^o$, $R2^o$, and $Q2^o$ are the values of R1, R2, and Q2 at the point (I_A, T_A), before any adjustment.

V_p^o is the voltage predicted by the un-adjusted parameters.

The predicted voltage, V_p, obtained by the use of adjusted parameters, R1, R2, Q2, is

$$V_p = V0 - \left(\frac{V1}{Q1}\right) Q - R1\ I_A - \left[\frac{R2Q2}{Q2 - Q}\right] I_A \qquad (4)$$

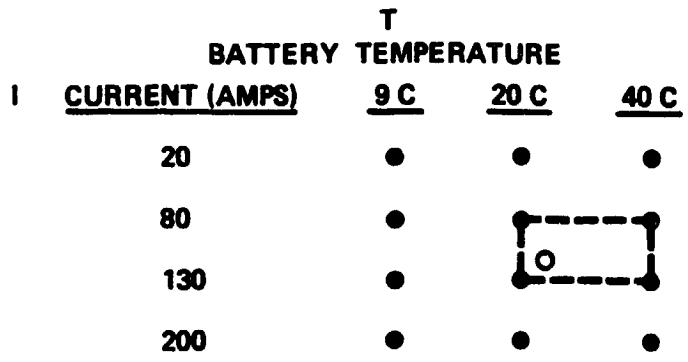
The error in battery impedance prediction is,

$$\Delta R \equiv \frac{V_m - V_p}{I} \qquad (5)$$

where V_m is the measured battery voltage, V_p is the predicted battery voltage, and I is the battery current.

The integral of the square of ΔR can be performed over all sections for which (I_A, T_A) is within a common zone. In this way, an increment to the parameters ΔR1, ΔR2, ΔQ2, which results in the lowest mean-squared error can be chosen (even though this increment results in different values of R1, R2, Q2 for each different (I_A, T_A) in each section). Then the change is distributed among the four operating corners which define the (I,T) zone. The mathematical model for this distribution is given on pages 64 through 66 in the original Final Report (Reference 1). The zone concept is illlustrated graphically in Figure 2.B.1. It is important to note that the only parameter values changed in the matrix were the bounding corners of the operating zone from which the recorded data was taken. Other points in the parameter matrix are left unchanged until actual recorded data is available in that zone in (I,T) space. This concept was a result of empirical studies of battery discharge data that revealed that changes in the battery parameters R1 and R2 in one zone of the (I,T) space did not necessarily correspond to proportional changes in the other zones of (I,T) space. The capacity parameter Q2 was found to have correspondingly proportional changes throughout (I,T) space with notable exception for the single zone with both the smallest I and T.

The investigations and testing early in the effort of Modification No. 5 concentrated on testing this original adaptor algorithm with the battery discharge library. It was found that this original adaptor performed quite well compared with the basic SOC algorithms used with no adaptation. Refer to pages 67 through 69 of the original Final Report. In Section 2.D of this report comparative test data is presented. However, this original adaptor was rejected as a candidate to include with the present SCI hardware and software package for the following reasons:



● REPRESENTS R1, R2 and Q2 AT A POINT IN I, T SPACE*

O REPRESENTS DISCHARGE DATA OPERATING POINT (HYPOTHETICAL)

-- ZONE OF INTERPOLATION USED IN ALL SOC PROGRAMS AND ALSO DISTRIBUTION REGION FOR ORIGINAL ALGORITHM

* Refer to Table 2.B.1 for numerical values.

(3985)

Figure 2.B.1 Operating zone in current, temperature space

1. The volatile memory space available in the present 2K byte RAM, namely 296 bytes, would not accommodate the numerous new Fortran variables and the extensive data records required for processing with the original adaptor.

2. The non-volatile memory space available in the present 16K byte PROM, namely 4K bytes, would not accommodate the lengthy programs and subroutines necessary to execute the original adaptor algorithm.

3. The processing time for the successive iterative loops in the original adaptor's programs may, in some cases, require over an hour.

4. The zone distribution of parameter "aging" provided no empirical estimates of aging in the zones of (I,T) space outside of the zone of the processed recorded data.

2.B.2.b Improved Parameter Adaptor Concept

The major effort of Modification No. 5 of this contract focused on simplifying and improving the original parameter adaptor concept. The first task was to analyze the modified Shepherd equation (given in equation (2) of this report) for its sensitivity to changes in each of the parameters Q2, R1 and R2. This was done for the encountered ranges of values for Q(t) and $I_F(t)$. Since V0, V1 and Q1 are always constants with respect to I_F and T, this sensitivity analysis was relatively straighforward. Gould's extensive library of battery discharge data provided a basis for examining these sensitivities.

By inspection, it is apparent that the parameter Q2 is the most sensitive one in equation (2) over a large portion of the range of Q. Also, due to the relative numerical values of the coefficients, the voltage predicted by Equation (2) is less sensitive to R1 and least sensitive to R2. With this knowledge, a test plan was conceived to exercise the state-of-charge (SOC) program on most of Gould's battery discharge test data files. A series of battery cell parameter arrays were generated based on the one given in Table 2.B.1. For each array the values of R1 and R2 were identical to the ones given in Table 2.B.1. Only the values of Q2 were changed in each successive array. To determine how to vary Q2 in these arrays, extensive data from runs

of the original adaptor were studied. In all cases the yardstick used to evaluate variances was the RMS error in SOC for runs of the SOC prediction program. Although empirical in nature, the following observations were uniformly conclusive:

1. As all of the tested batteries aged, the long-term trend was always a reduction in Q2. This was found to be true for all ranges (of interest) of battery current and temperature.

2. There was no predictable trend in the aging of parameters R1 and/or R2. For some batteries, R1 would actually vary up and down with aging. Furthermore there was no uniform correlation of behavior in R1 or R2 over wide ranges of current or temperature.

3. By adjusting only the parameter Q2 in the cell parameter array (Table 2.B.1) the RMS error in SOC predictions could be minimized to a remarkable degree.

The effect of varying the battery parameters on the voltage prediction equation is illustrated in Figures 2.B.2 through 2.B.4. Note that Q2 provides the basic "bias" to the curves and that R1 and R2 provide, to a degree, information about the slope of the curves. Furthermore, Q2 provides the key to the amount of energy available. It was found that even 100% variations in R1 and R2 had minimal impact on average energy considerations.

To develop an effective algorithm from this knowledge, practical considerations must be inferred from the basic contract goals of SOC accuracy. The stated accuracy goal of +0%, -20% clearly indicates that conservative SCI readings are mandatory. Practical electric vehicle usage dictates that accuarcy is most critical when the batteries are near exhaustion, i.e., SOC indication 30% or less.

It is from the heretofore considerations that the revised parameter adaptor concept was developed:

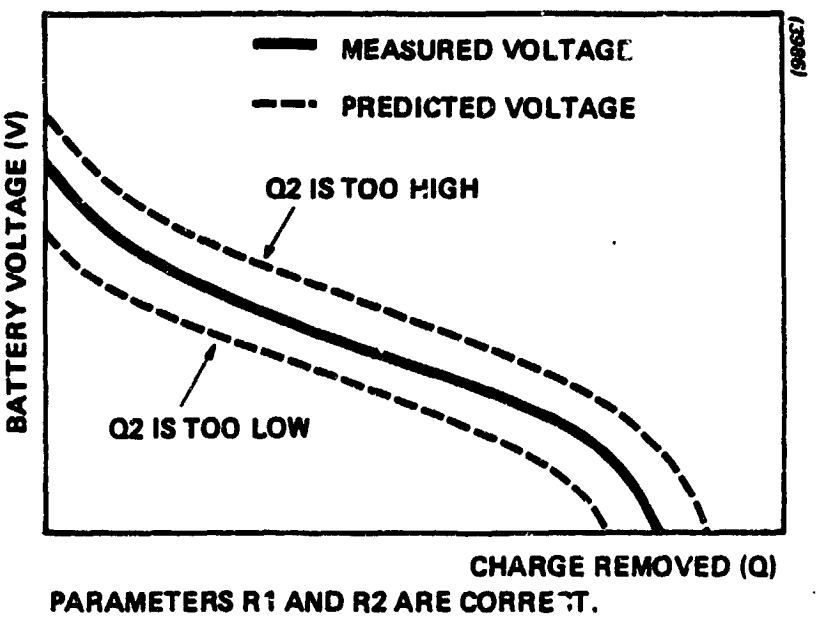
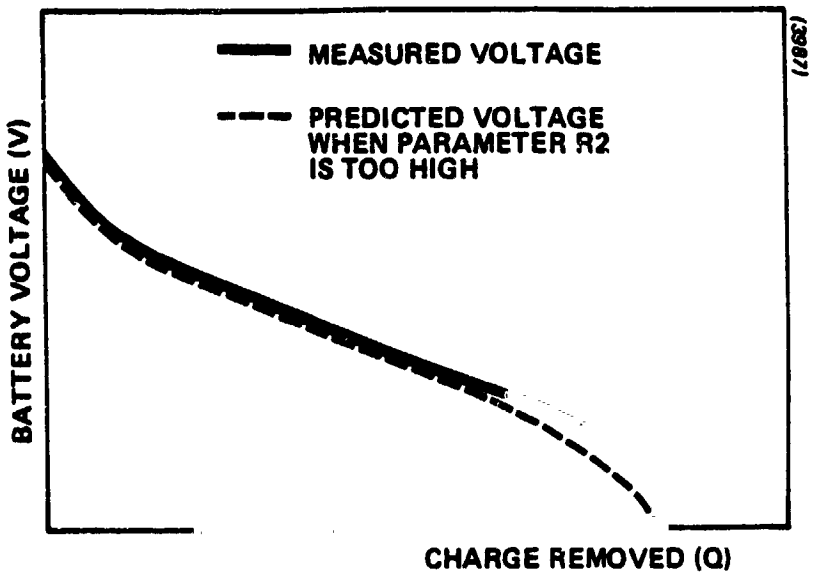


Figure 2.B.2 Predicted and measured battery voltage vs. charge removed (hypothetical)



PARAMETERS R1 AND Q2 ARE CORRECT.

Figure 2.B.3 Predicted and measured battery voltage vs. charge removed (hypothetical)

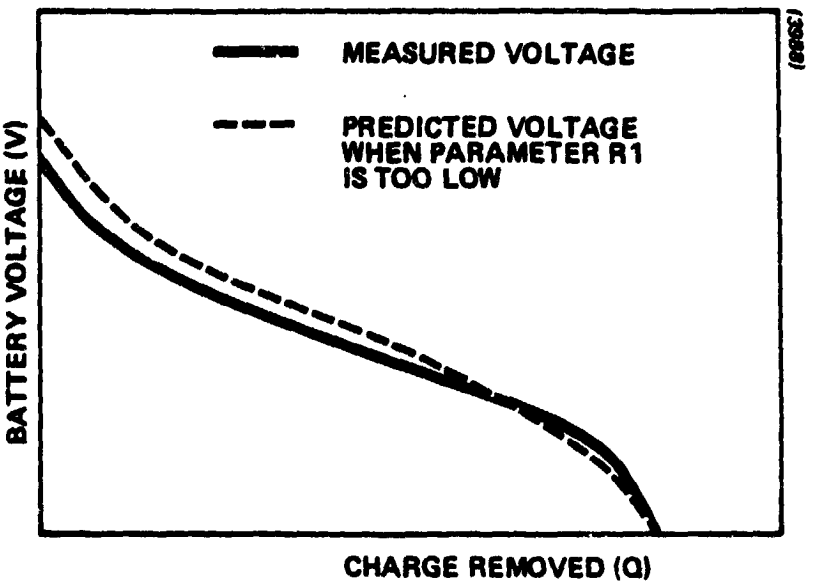

MEASURED VOLTAGE
PREDICTED VOLTAGE WHEN PARAMETER R1 IS TOO LOW
BATTERY VOLTAGE (V)
CHARGE REMOVED (Q)
PARAMETERS R2 AND Q2 ARE CORRECT.

Figure 2.B.4 Predicted and measured battery voltage vs. charge removed (hypothetical)

1. Only the parameter Q2 will be adapted, or changed, as the batteries are used. The array values of R1 and R2 will not be adapted. This would allow error minimization to: be simplier, be more effective and, most critically, fit in the existing SCI memory.

2. The parameter Q2 will be adjusted proportionally throughout (I,T) space in the parameter array rather than just in the most recent operating zone as with the original adaptor concept. Proportional adjustment has been shown empirically to be accurate and when errors did occur, they would yield conservative predictions when SOC readings were less than 30%.

3. For parameter adaptation purposes, battery discharge data would be considered only after the battery had been discharged past the 50% mark of SOC. Actually, this is defined as when the charge removed, Q(t), exceeds one half of Q2E (the interpolated value of Q2 with respect to I_F and T). This consideration is necessary to compensate for the actual deviations that might occur in the prediction equation due to the lack of adaptation of R1 and R2, a critical element in insuring that errors are conservative.

2.B.3 Improved Parameter Adaptor Algorithms

An algorithm consisting of curve fitting alone is not sufficient to execute the improved battery parameter concept. If the battery discharge data records represent a relatively constant power (or constant current) dc discharge, then an effective error minimization algorithm can be used to adapt the parameter Q2. Unfortunately, electric vehicle driving cycles are not ideal dc discharges. Many realistic driving conditions will not yield relatively continuous or smooth (constant power) discharge data for periods of time sufficient to consider using a parameter optimization based on a curve-fitting, error minimization routine. An incremental default algorithm was developed which would provide an empirical aging estimate for the parameter Q2 if the discharge data records are too erratic for using the error minimization algorithm. These algorithms would be performed in the think mode after the charge mode has been completed.

2.B.3.a Error Minimization Algorithm

The error minimization algorithm (EMA) is preceded by a data validity test for the recorded discharge data. It requires that recording of certain discharge data be accomplished during the Discharge Monitor mode.

The battery discharge data recorded during the discharge monitor mode includes the battery terminal voltage, V_m, filtered current, I_F, charge removed, Q, filtered battery temperature, T, and the error in battery"impedance" prediction, ΔR. In order to maximize accuracy with a minimum of volatile memory requirement, the following algorithm is employed for this data collection:

1. Data recording commences only when the battery has been discharged below approximately 50% of capacity. This is defined to be when the charged removed, Q, is greater than one-half of Q2E (the interpolated value of Q2, for the particular values of I_F and T).

2. The filtered temperature, T, is recorded at the beginning of the data recording.

3. Up to nine data records are recorded approximately four minutes apart. This includes V_m, I_F, Q and ΔR for each data record.

4. Should the time of discharge data recording yield more than nine data records, the data will be indexed such that the nine most recent data records are kept in memory record. Thus this would yield the most recent 36 minutes of data.

5. The filtered temperature, T, is recorded again (and updated if directed by the indexing) at the same time as the final data record is recorded.

When the think mode is run after the charge mode, a data validity test is run first. In order to run the error minimization algorithm (EMA), the data recorded in the discharge monitor mode must conform to the following criteria:

1. At least four consecutive data points must have power ($V_m \cdot I_F$) constant to within + 10% or -10%, and,

2. The most recent data point must be less than 125% of the cutoff voltage, defined here to be $V_m < 1.77$ volts/cell, and

3. Valid data records must not contain any regeneration ($I_F > 0$).

If the data does not pass this test at least once between every equalization charge, then the Incremental Default Algorithm (IDA) will be run in lieu of the EMA.

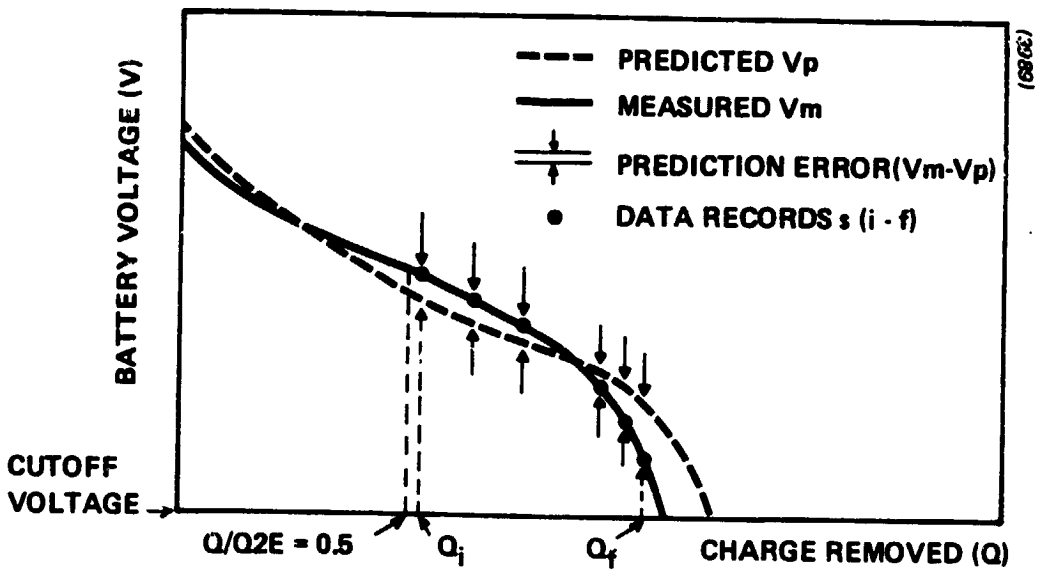
If the data passes the data validity test, then EMA will be run. This accomplishes parameter adpatation by changing Q2 to conform to a curve-fit for the temperature and current zone of the particular discharge data profile run. This is done by minimizing an approximate integral squared error in battery "impedance",

$$E = \int_{Q_i}^{Q_f} (\Delta R)^2 \, dQ \qquad (6)$$

through successive pertubations of the parameter Q2E. Q2E is the interpolated value of the Q2 array for the particular zone of current and temperature of the subject discharge data. A hypothetical error is illustrated in Figure 2.B.5. A new set of ΔRs and thus a new E is calculated for each successive perturbation in Q2E. If the new E is lower than the previous E, then the iterative process continues. The perturbation step size in Q2E is 1% and the maximum allowable change in Q2E is limited to 5%. In order to insure the conservative accuracy desired (+0%, -20%), the average error in voltage prediction, ΔV_A, is used to determine whether Q2E will be decreased, increased, or not changed.

ΔV_A is defined as:

$$\Delta V_A = \frac{1}{Q_f - Q_i} \int_{Q_i}^{Q_f} \Delta R \cdot I_F \, dQ \qquad (7)$$



ERROR IN BATTERY "IMPEDANCE" PREDICTION AT ANY INDIVIDUAL DATA RECORD:

$$\Delta R = \frac{Vm - Vp}{I}$$

WHERE I IS THE RECORDED CURRENT OF THAT DATA RECORD

Figure 2.B.5 Error in voltage prediction and "Impedance" prediction (hypothetical).

where Q_i is the charged removed for the initial valid data point and Q_f is the charge removed for the final valid data point. Table 2.B.2 give the values for ΔV_A that determine how the adaptation will proceed.

Table 2.B.2

Parameter Q2 Change Determined by Average Error in Voltage Prediction

Average Error in Voltage Prediction (ΔV_A)	Q2 Will:
$\Delta V_A \leq +20$ millivolts/cell	Be Decreased
$+20$ millivolts/cell $< \Delta V_A \leq +50$ millivolts/cell	Not be Changed
$\Delta V_A > +50$ millivolts/cell	Be Increased

After the iterative process is complete each Q2 in the parameter array is changed proportionally. This is done with linear extrapolation and equal weighting for all points in (I,T) space.

2.B.3.b Incremental Default Algorithm

As stated previously, the Incremental Default Algorithm (IDA) will run after an equalization charge if EMA has not run since the previous equalization charge. IDA provides an empirical aging estimate for decreasing Q2 and, in some cases, may provide for a slight increase in Q2.

In order to insure the conservative accuracy desired (+0%, -20%), two distinct average errors in voltage prediction are calculated and used to determine whether Q2 will be decreased, increased or not changed. One of these errors in voltage prediction (VERR) is the one calculated during the wake up mode (or rest mode) and is based on the equilibrium battery voltage. The dynamic error in voltage prediction is calculated once each pass through the discharge monitor loop:

$$VDEL = V_m - V_p \qquad (8)$$

where V_m is the measured battery voltage and V_p is the predicted battery voltage. After the battery has been discharged 50% (Q > 0.5 Q2E) a weighted average voltage error, VDELF, is calculated and updated for each pass through the discharge monitor loop. Thus at the end of each driving cycle the average voltage error is:

$$VDELF = \frac{1}{QTOTAL} \sum_{n=1}^{N} VDEL_n \cdot Q_n \tag{9}$$

where n represents a pass through the discharge monitor, N is the total number of passes and QTOTAL represents the total charge removed over the interval.

During the charge mode each day the weighted average VDELF is updated since the last equalize charge, thus,

$$VDELT = \frac{1}{QABS} \sum_{d=1}^{D} VDELF_d \cdot QDIS_d \tag{10}$$

where d represents a day, D is the total days since the last equalize charge, QDIS is the total charge removed (discharged) during day d and QABS represents the total charged removed (discharged) since the last equalize charge.
The Incremental Default Algorithm (IDA) can now be defined as follows:

1. If both the average voltage prediction errors (VDELT and VERR) are less than +20 millivolts/cell, then all values of Q2 in the array will be reduced by the formula:

   $$Q2 \text{ new} = Q2 \text{ old} \cdot (1 - 5X10^{-5} \cdot QABS) \tag{11}$$

   Thus 500 amp-hours would yield a 2.5% reduction in Q2. The maximum decrease allowed is set at 2.5% per equalization cycle.

2. If both the average voltage prediction errors (VDELT and VERR) are greater than +50 millivolts/cell, then all values of Q2 in the array will be increased by the formula:

   $$Q2 \text{ new} = Q2 \text{ old} \cdot (1 + 2X10^{-5} \cdot QABS) \tag{12}$$

Thus 500 amp-hours would yield a 1% increase in Q2. The maximum increase allowed is set at 1% per equalization cycle.

3. For all other values (or combinations of values) of the VDELT and VERR voltage prediction errors, there would be no change in Q2.

The "aging" estimate represents a reduction in "capacity" (Q2) of 0.005% per amp-hour of discharge. If the batteries are cared for properly and are charged according to the algorithm in the original BC/SCI, then this aging factor would be somewhat greater than empirical data would indicate. Thus the resulting SCI readings would tend to be conservative. In typical operation, IDA might "age" Q2 by the amount given in Equation (11) during one cycle. If this were too much it would be reflected by an increase in the voltage prediction error(s) during the next cycle with a resulting "no change" in Q2 calculated by IDA.

The increase in Q2 afforded by the IDA algorithm is very slight, in line with the conservative nature of the contract goals. Increases in battery capacity are very unpredictable and are somewhat risky to estimate on an empirical basis.

2.B.4 Anomalous Behavior Modifications

During the testing of the original SOC algorithm at JPL, two operational cases were noted which appeared to cause the displayed SOC to be in error. The first of these occured when the BC/SCI was toggled between off and the discharge monitoring mode. The calculated SOC was decremented by the rapid cycling between these two modes independent of the actual battery SOC.

The original design intent was to account for a decline in battery capacity between equalize charges. When the BC/SCI is powered-on, it momentarily enters the charge mode and notes that an equalize charge has not occured between discharges (as indicated by entering the discharge monitoring mode). It then decrements the calculated SOC. Since the revised [illegible] no longer controls the charger, this operational characteristic has been completely removed from the system softwa.e.

The second operational anomaly occured at the end of discharge. The indicated zero SOC initially agrees with the exhausted battery, however, the indicated SOC increases after the discharge terminates. Two factors are responsible for this behavior. The first is the behavior of the battery itself. During discharge, an electrolyte concentration gradient develops restricting the amount of acid available for reaction with the battery plates. This gradient diffuses upon termination of the discharge causing an increase in the available battery energy. The SOC algorithm accounts for this behavior and increases the indicated state-of-charge. This battery recuperation alone will not account entirely for the increase in the SOC. The second factor is the structure of the basic SOC algorithm. The actual battery terminal voltage is always compared to the calculated voltage as a check on the accuracy of the SOC projection. Under most circumstances, the small differences do not influence the SOC calculation. However, when a high-rate discharge terminates abruptly as in the JPL testing, there exists a large difference between the actual cell voltage and the predicted voltage. Under these circumstances, the "confidence" in the predicted voltage is low, and the actual cell voltage has a strong influence on the indicated SOC. Modifications to correct this behavior require restructuring the state-of-charge algorithm and are not considered advisible in view of the revised system accuracy goals.

2.C Software Description

The software for the improved SCI employs both 6809 assembly and Fortran programming languages. The software has been carefully structured to benefit from advantages provided by each language without sacrifice in overall system performance. The changes and additions made during Modification No. 5 were primarily in the Fortran language.

The real time executive provides the basic data acquisition and hardware interface functions. These tasks are characterized by being time critical in nature and are repeated at a fairly high rate (i.e., every 0.133 sec). Such requirements benefit greatly from the speed and bit manipulating capability provided by assembly programming.

The state-of-charge and the parameter adaptor algorithms on the other hand are highly mathematical in nature. Sophisticated arithmetic operations having wide dynamic ranges are among the technical requirements. Flexibility for future enhancements also favor a high-level programming solution. Fortunately these functions are not as time critical as the data acquisition for adequate performance (i.e., every 15 sec.). Fortran satisfies these requirements but does suffer the disadvantage of excessive memory requirements typical of high level languages.

The system has been structured so that the real time executive is the primary controlling module. The executive has the ability to call any one of five primary Fortran subroutines as is shown by the revised hierarchy chart in Figure 2.C.1. The chart clearly shows all BC/SCI Fortran modules and how each is called by the five primary subroutines. A revised glossary is included in Appendix 1 which briefly describes the specific function of each module.

The flowcharts in Figures 2.C.2 - 2.C.8 illustrates the revised software structure as reflected by Modification No. 5. The reader may refer to the original Final Report (Reference 1) for additional information on the original software operation.

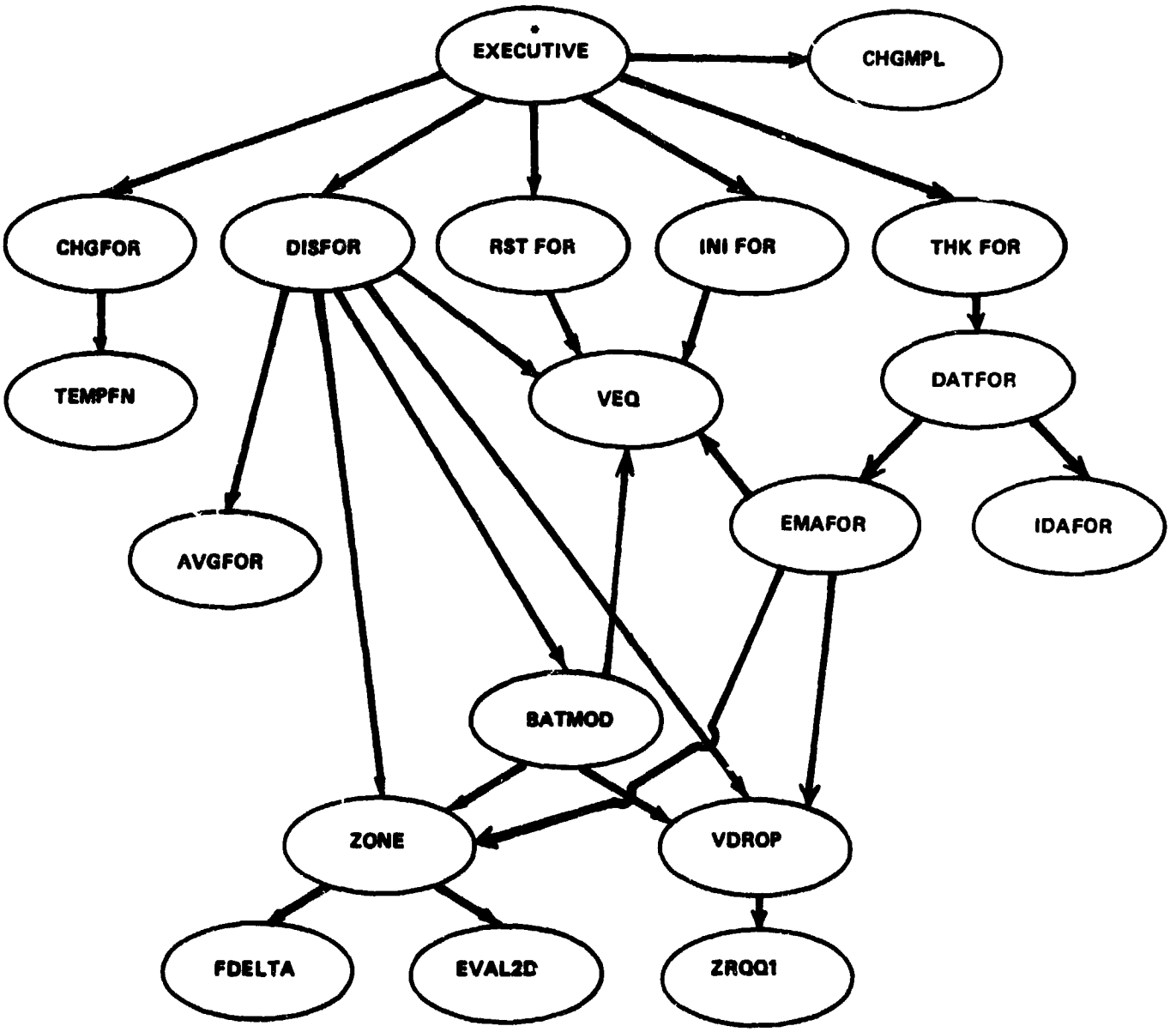


Figure 2.C.1 Hierarchy of improved SCI subprograms.

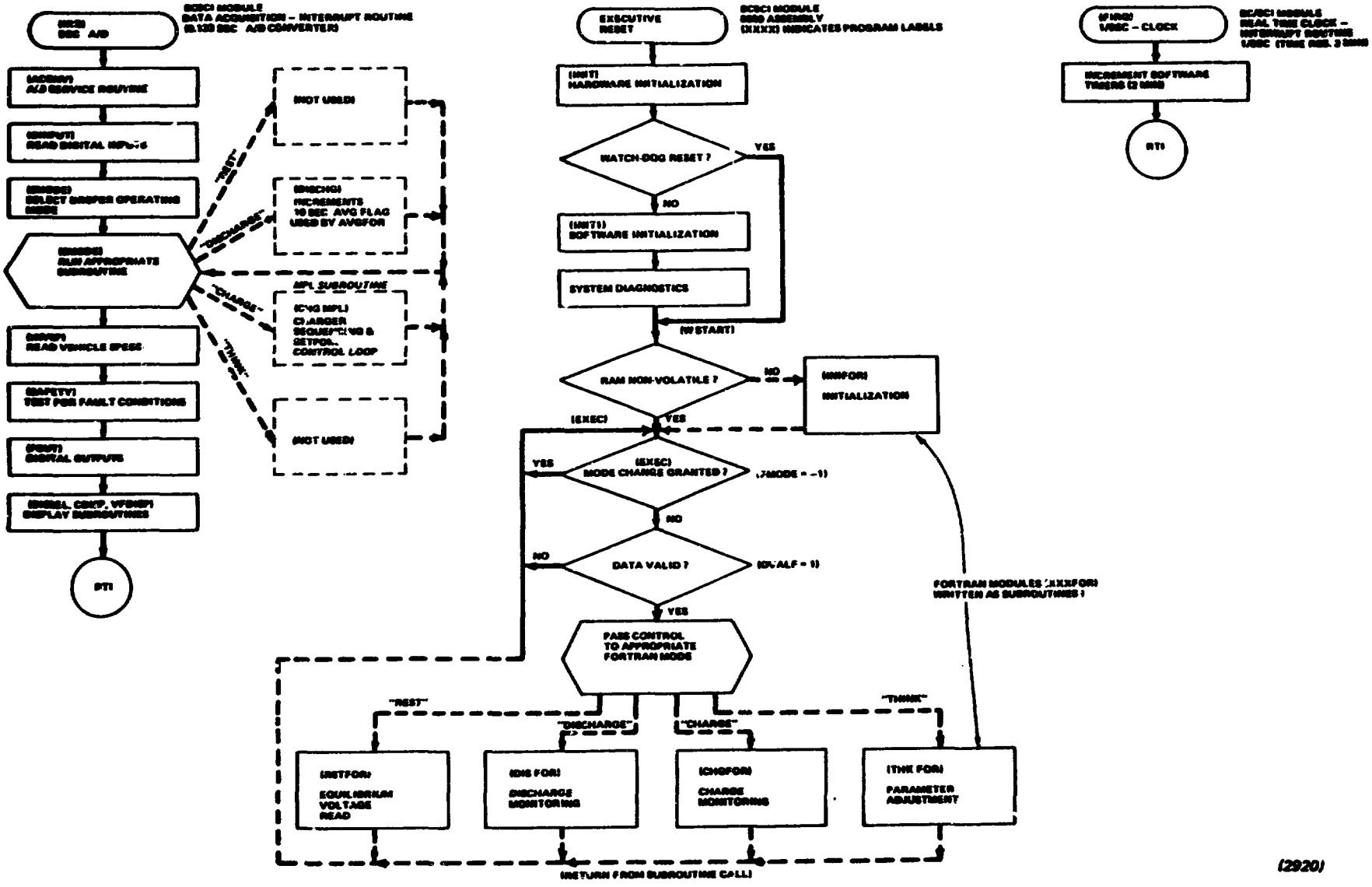


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Figure 2.C.2 Software module interaction

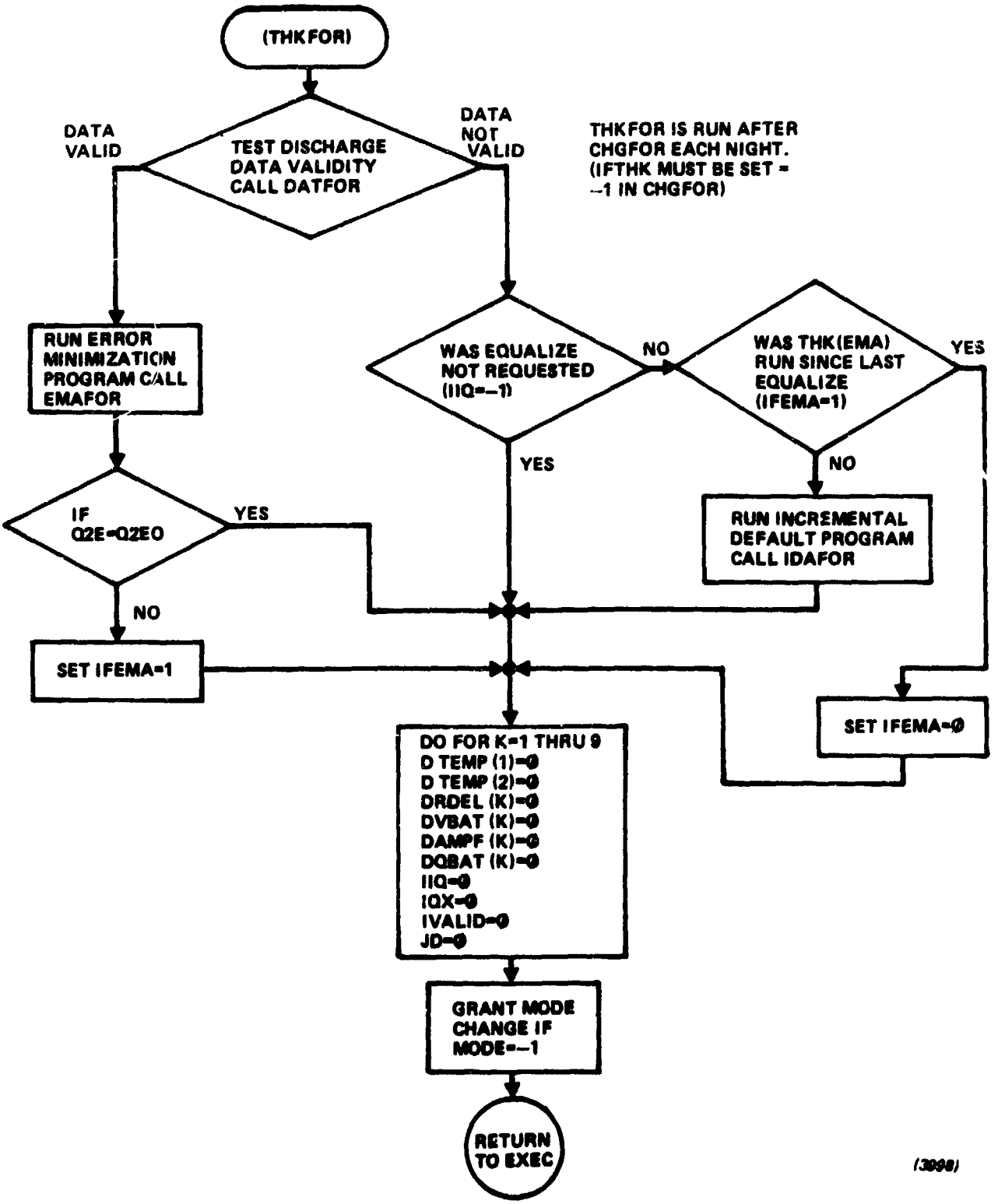


Figure 2.C.3 Improved think mode-THKFOR written in Fortran.

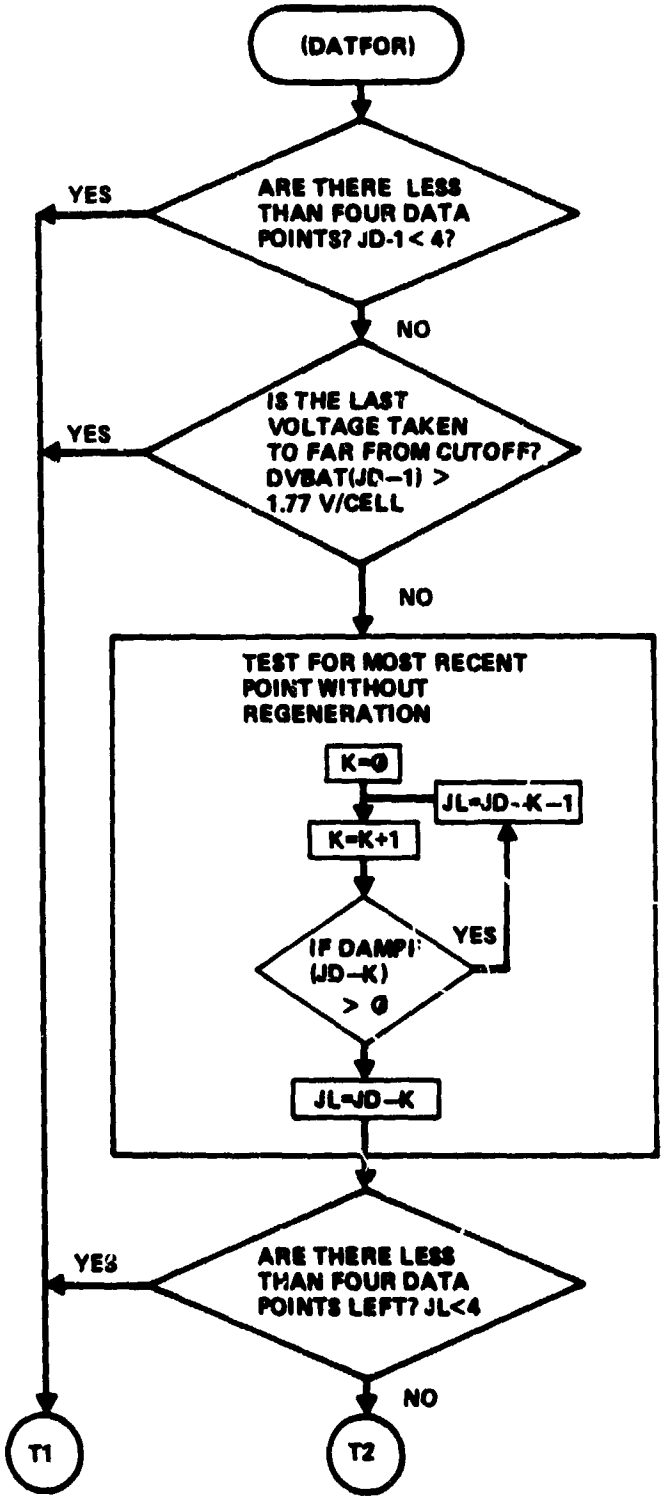


Figure 2.C.4 Improved data test-DATFOR written in Fortran. (cont.)

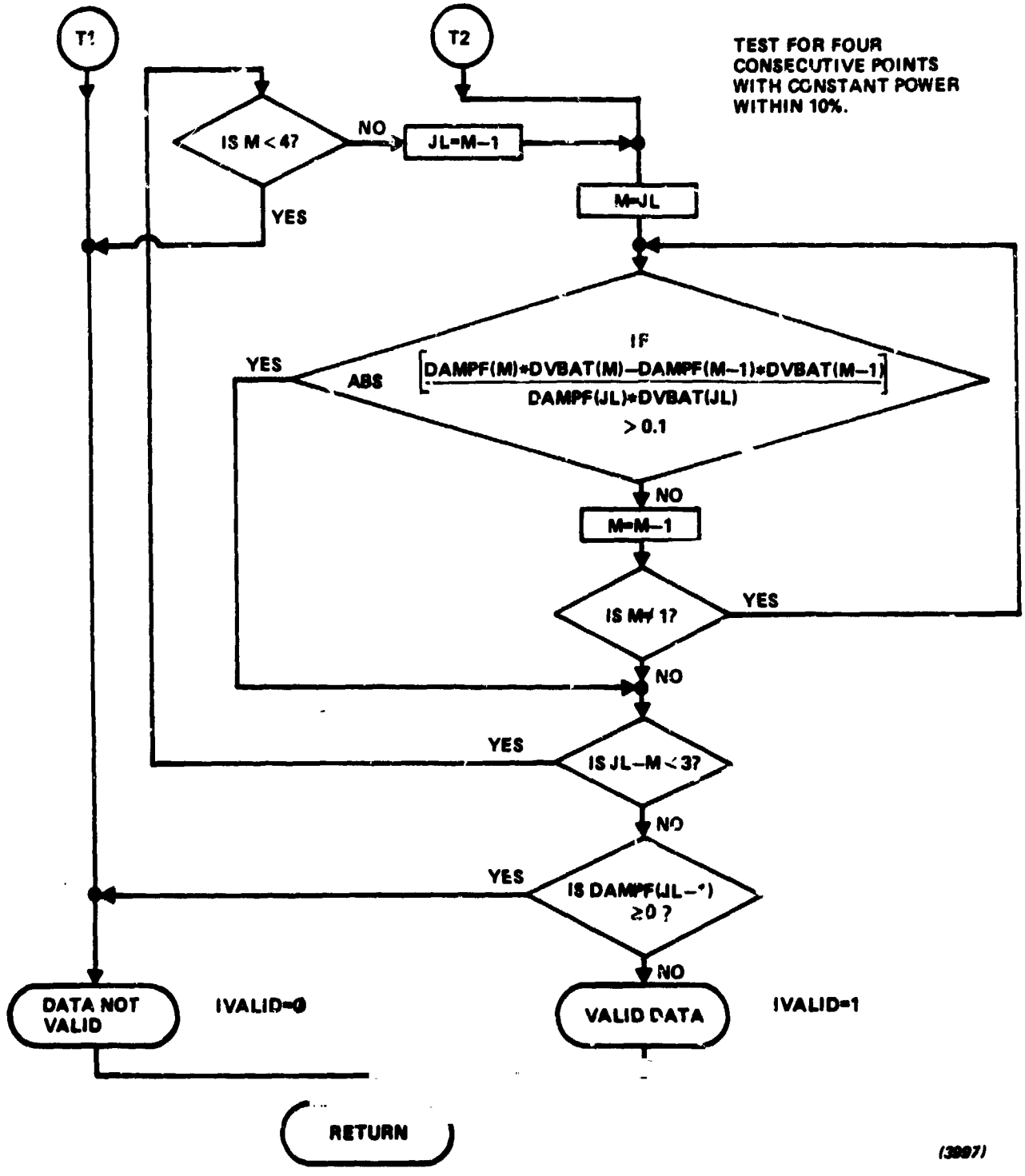
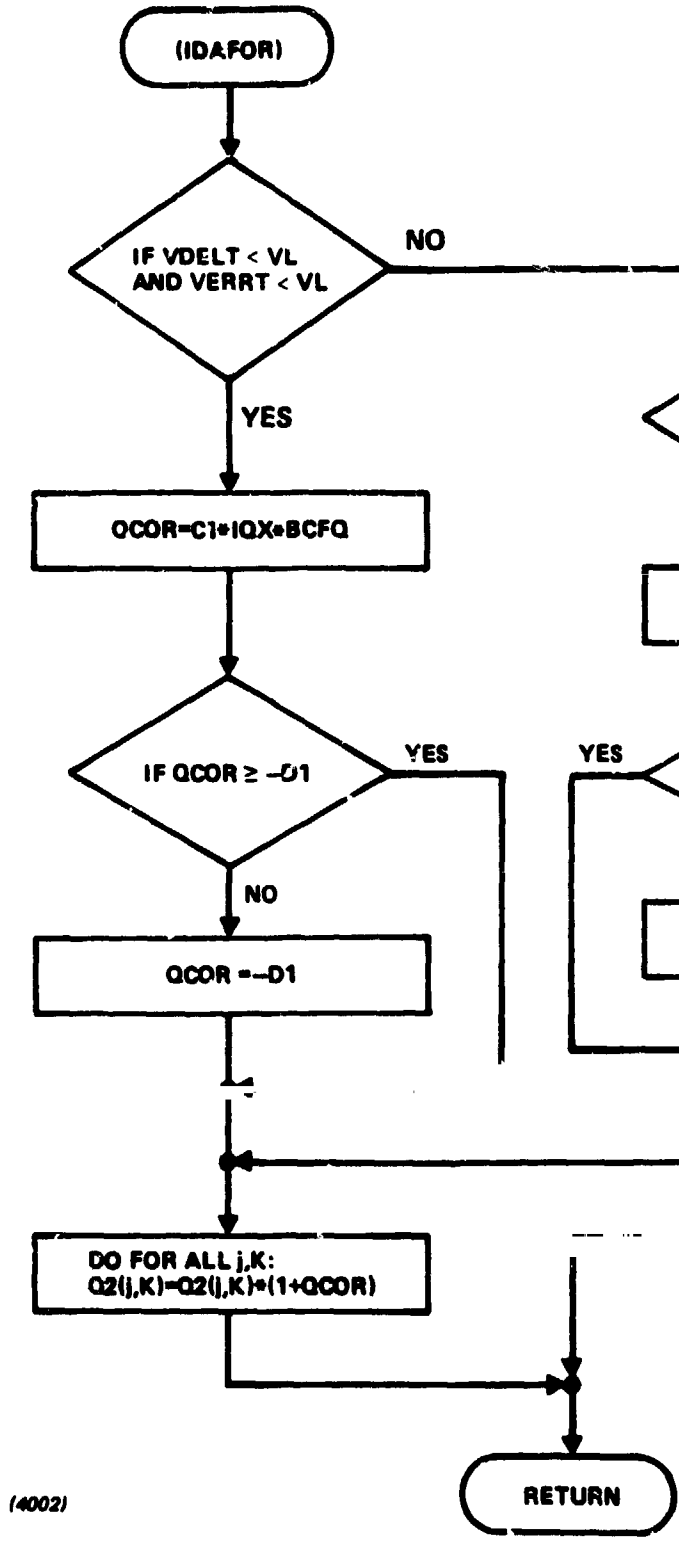


Figure 2.C.4 (cont.) Improved data test-DATFOR written in Fortran.



NOTES ON THK (IA)

1. Q2 (4,3)'s ARE ALL STORED AS NEGATIVE VALUES.
2. VL= 0.020 VOLTS
   VH=0.050 VOLTS
   C1= 5.0x 10^{-5}
   C2= 2.0x 10^{-5}
   D1= 0.023
   D2=0.01
3. IQABS*BC2F REPRESENTS CUMMULATIVE AMP-HRS. OF DISCHARGE (USAGE) SINCE LAST EQUALIZE AND IS NEGATIVE NUMBER.

Figure 2.C.5 Improved incremental default algorithm-IDAFOR written in Fortran.

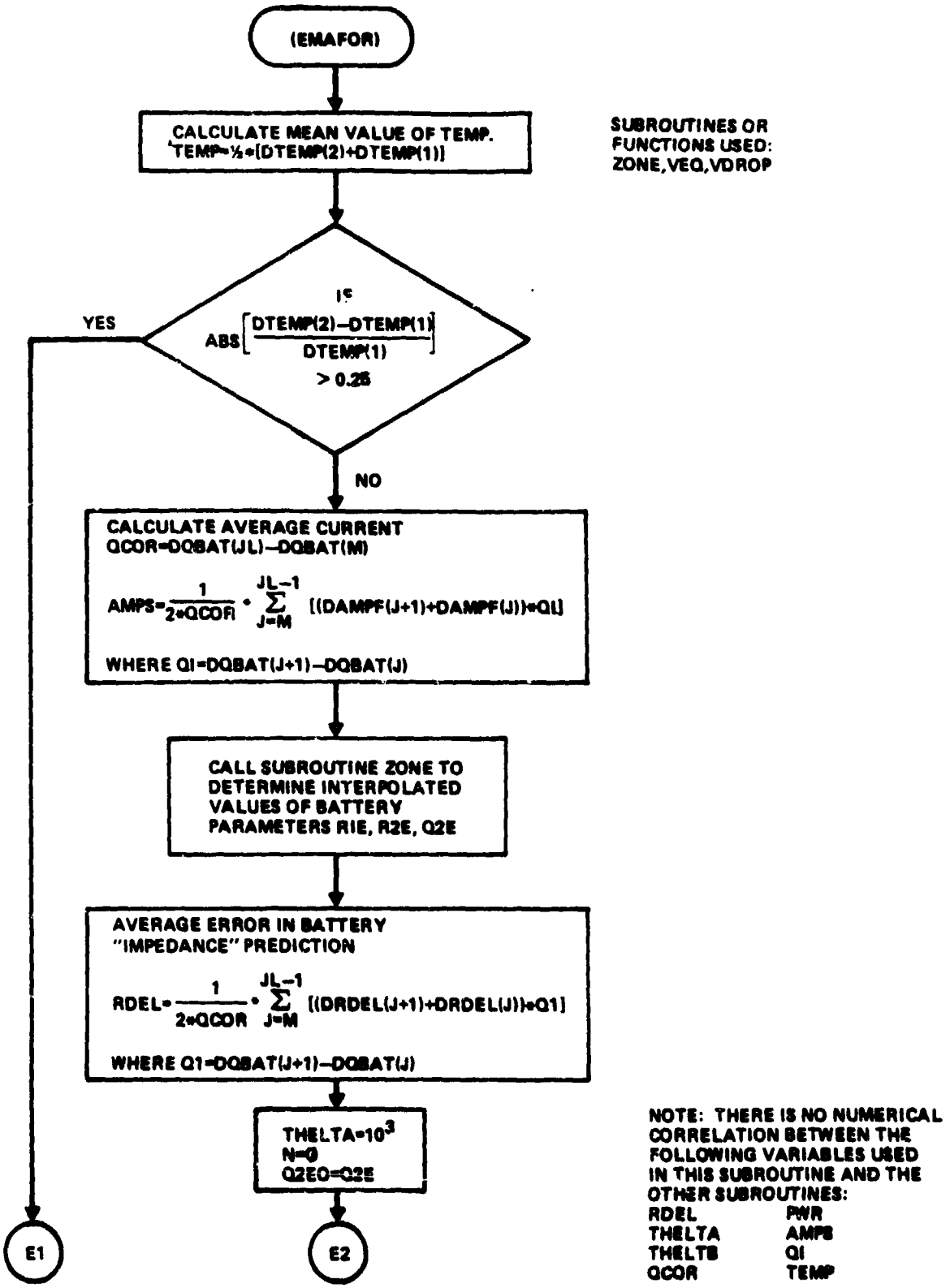


Figure 2.C.6 Improved error minimization algorithm-EMAFOR written in Fortran.

(3999)

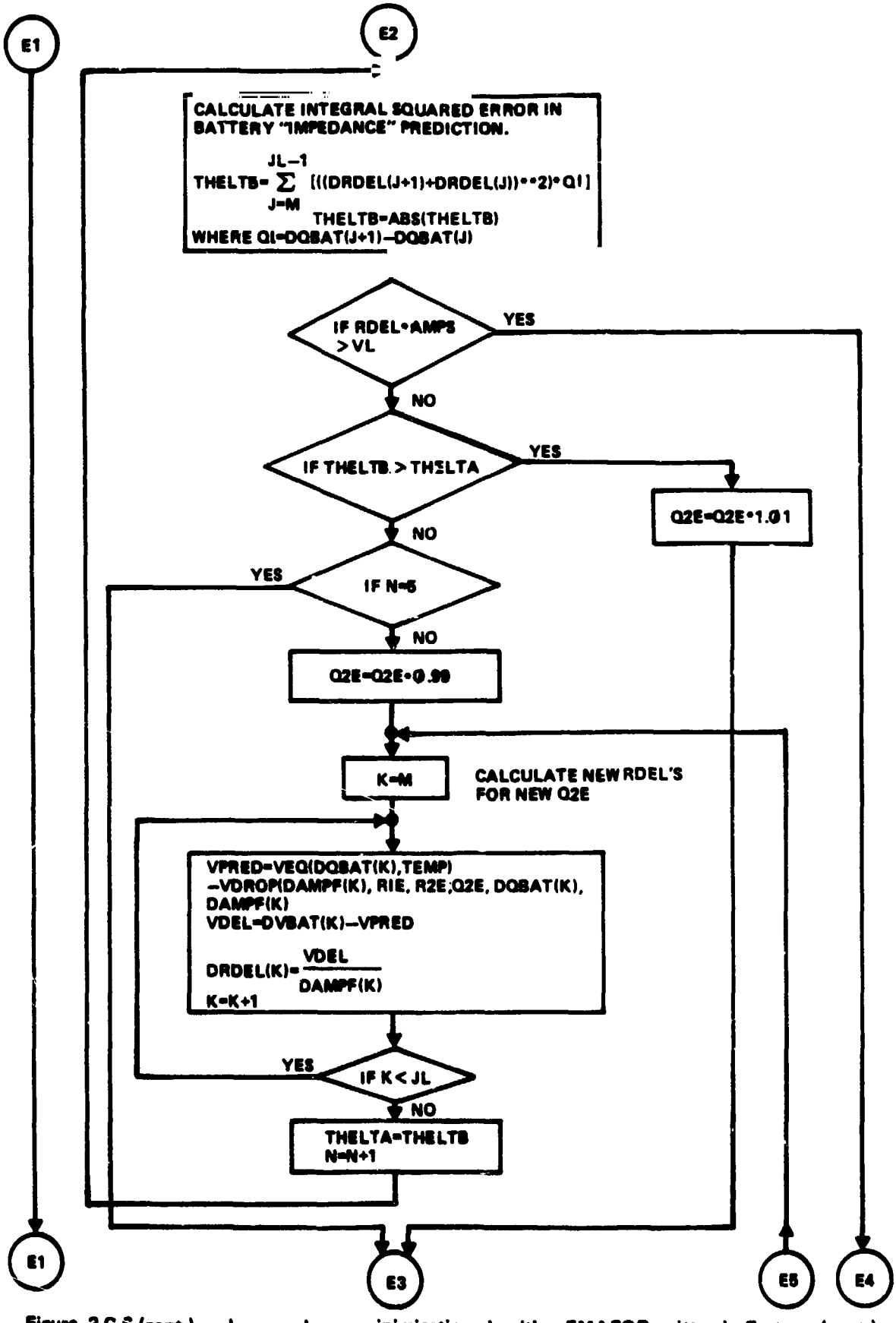


Figure 2.C.6 (cont.) Improved error minimization algorithm-EMAFOR written in Fortran. (cont.)

(4000)

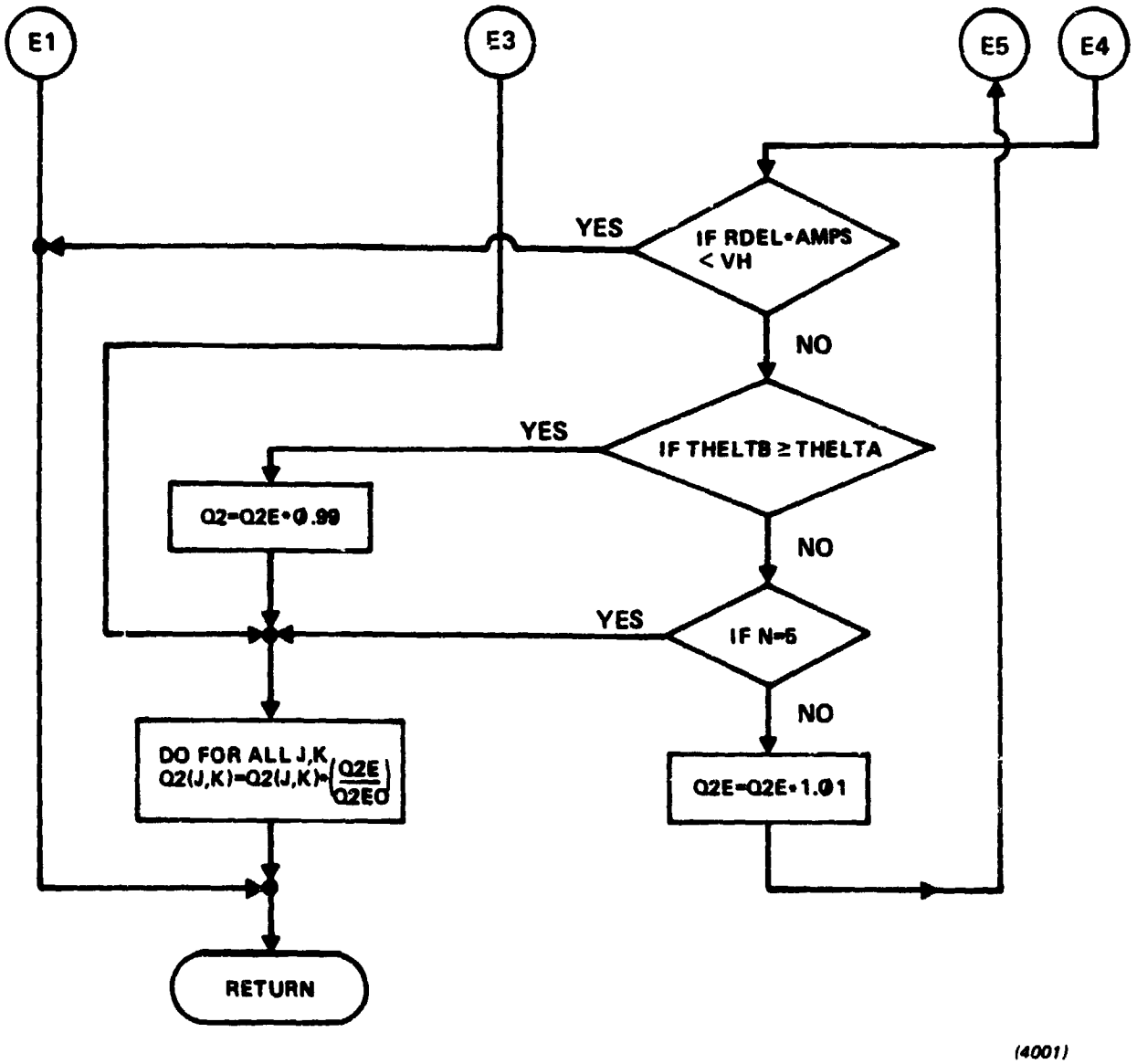


Figure 2.C.6 (cont.) Improved error minimization algorithm-EMAFOR written in Fortran.

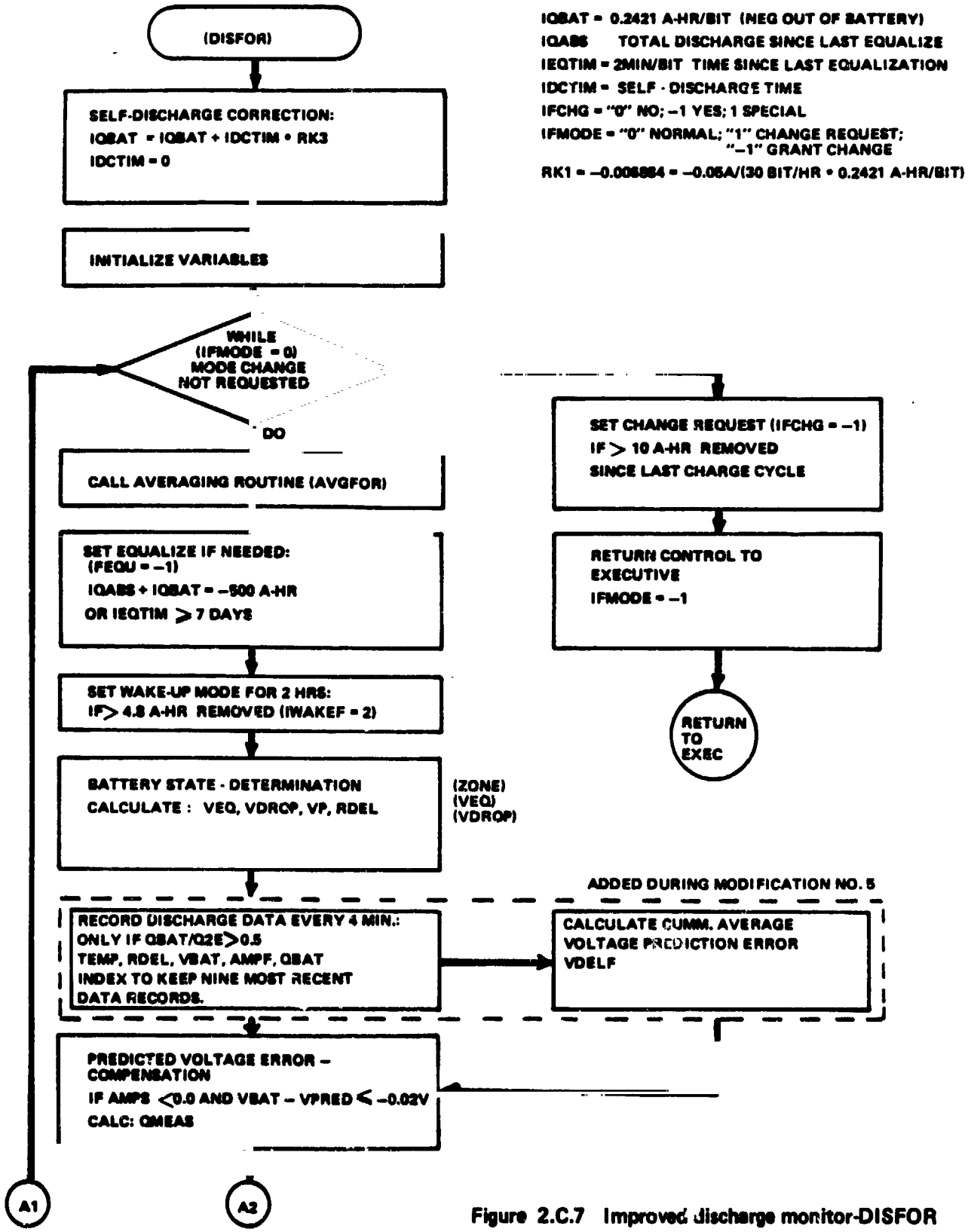

IQBAT = 0.2421 A-HR/BIT (NEG OUT OF BATTERY)
IQABS TOTAL DISCHARGE SINCE LAST EQUALIZE
IEQTIM = 2MIN/BIT TIME SINCE LAST EQUALIZATION
IDCTIM = SELF - DISCHARGE TIME
IFCHG = "0" NO; –1 YES; 1 SPECIAL
IFMODE = "0" NORMAL; "1" CHANGE REQUEST; "–1" GRANT CHANGE
RK1 = –0.008884 = –0.05A/(30 BIT/HR • 0.2421 A-HR/BIT)
(DISFOR)
SELF-DISCHARGE CORRECTION:
IQBAT = IQBAT + IDCTIM • RK3
IDCTIM = 0
INITIALIZE VARIABLES
WHILE (IFMODE = 0) MODE CHANGE NOT REQUESTED
DO
CALL AVERAGING ROUTINE (AVGFOR)
SET EQUALIZE IF NEEDED: (FEQU = –1)
IQABS + IQBAT = –500 A-HR
OR IEQTIM > 7 DAYS
SET WAKE-UP MODE FOR 2 HRS:
IF > 4.8 A-HR REMOVED (IWAKEF = 2)
BATTERY STATE - DETERMINATION
CALCULATE : VEQ, VDROP, VP, RDEL
(ZONE)
(VEQ)
(VDROP)
ADDED DURING MODIFICATION NO. 5
RECORD DISCHARGE DATA EVERY 4 MIN.:
ONLY IF QBAT/Q2E > 0.5
TEMP, RDEL, VBAT, AMPF, QBAT
INDEX TO KEEP NINE MOST RECENT DATA RECORDS.
CALCULATE CUMM. AVERAGE VOLTAGE PREDICTION ERROR VDELF
PREDICTED VOLTAGE ERROR – COMPENSATION
IF AMPS < 0.0 AND VBAT – VPRED ≤ –0.02V
CALC: QMEAS
SET CHANGE REQUEST (IFCHG = –1)
IF > 10 A-HR REMOVED
SINCE LAST CHARGE CYCLE
RETURN CONTROL TO EXECUTIVE
IFMODE = –1
RETURN TO EXEC
A1
A2

Figure 2.C.7 Improved discharge monitor-DISFOR written in Fortran.

(2917)

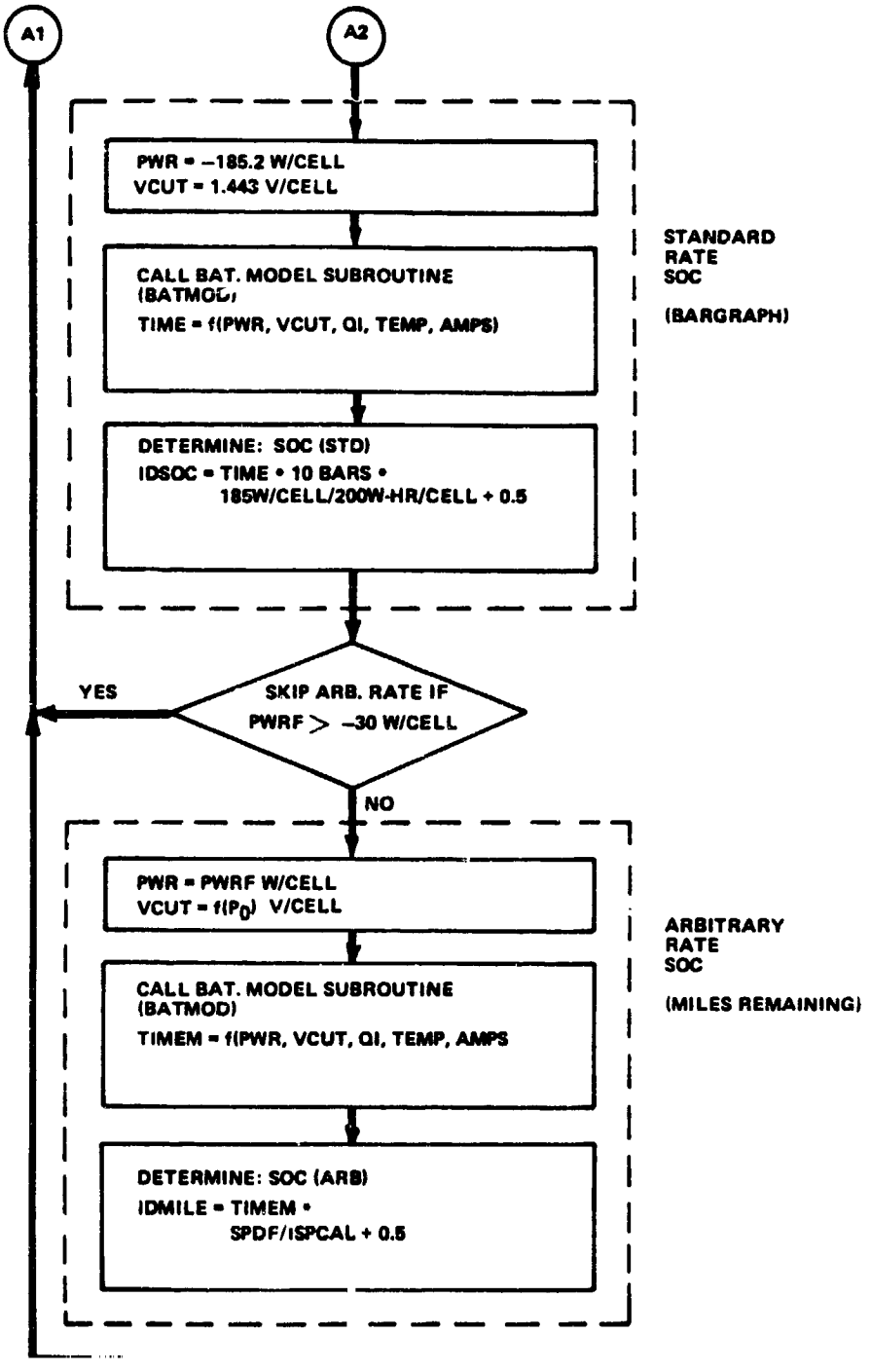


Figure 2.C.7(cont.) Improved discharge monitor-DISFOR written in Fortran.

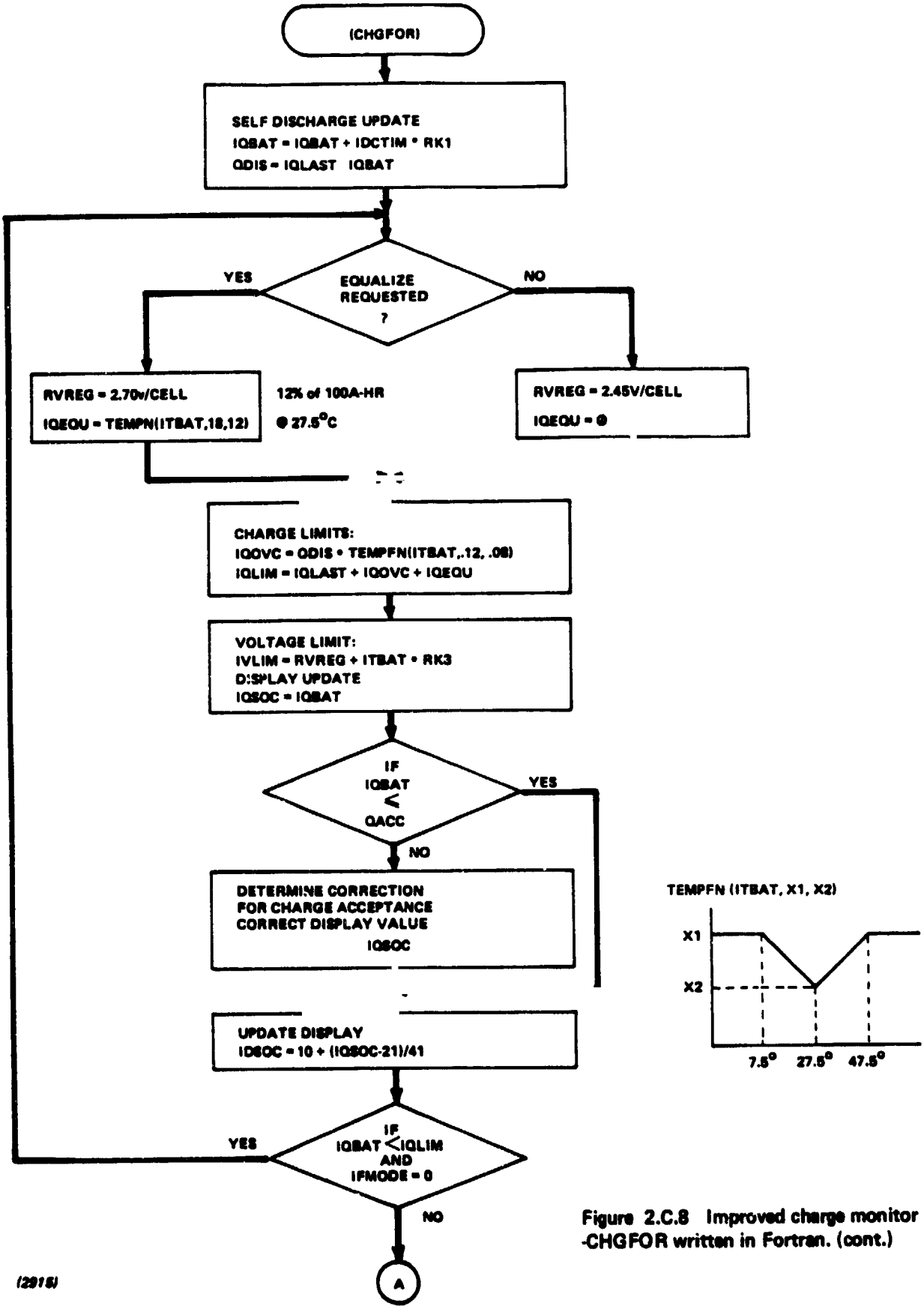
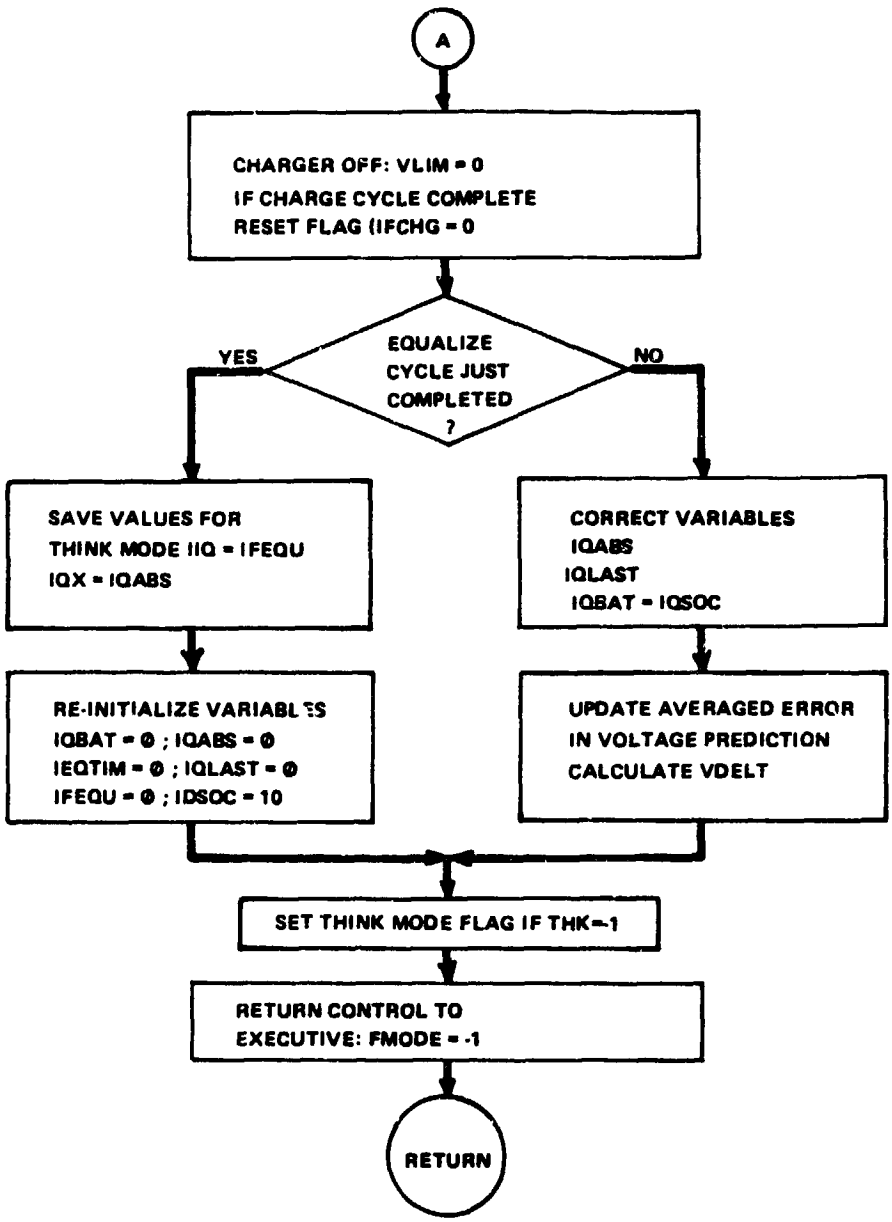


Figure 2.C.8 Improved charge monitor -CHGFOR written in Fortran. (cont.)



IEQUTIM = 2MIN/BIT — TIME SINCE LAST EQUALIZE CYCLE
IDISTIM = 2MIN/BIT — TIME SINCE LAST DISCHARGE CYCLE
IQBAT = .2421 A-HR/BIT — AMP-HOUR METER "NEG OUT OF BAT"
ITBAT = 1°C/BAT — BATTERY TEMPERATURE
IVLIM = .050V/BIT — VOLTAGE LIMIT DURING CHARGE
IFEQU = ØNORMAL; -1 EQUALIZE; -256 DEFER
IFMODE = Ø NORMAL; 1 = CHARGE REQUESTED; -1 = CHARGE GRANT
IQABS = — A-HR REMOVED SINCE LAST EQUALIZE CYCLE
RK1 = .05A/(30BIT/HR) * .2421 A-HR/BIT
RK3

(2916)

Figure 2.C.8 (cont.) Improved charge monitor - CHGFOR written in Fortran.

The normal program execution starts with the executive performing the system initialization. It determines which mode has been selected and checks for valid data. Since the data acquisition is asynchronous to the main program execution, the executive must wait until the A/D conversion cycle is completed after which the data valid flag is set (DVALF=1). The executive then passes control to the appropriate Fortran subroutine shown in Figure 2.C.2.

To guarantee controlled interaction a simple handshaking scheme was developed. If FMODE=0, the Fortran program can operate normally. When this flag is set (FMODE=1) by the interrupt program (i.e., operator requesting a mode change) the Fortran program must orderly complete whatever its doing, acknowledge the request (FMODE=-1) and return control back to the executive. The executive may then select a new mode, or the interrupt program can shut the system down depending upon requirements. This rigorous sequence guarantees predictable system operation whether the Fortran program is written with a looping (CHGFOR, DISFOR, THKFOR, EMAFOR) or sequential (RSTFOR, INIFOR) program structure.

The common area in RAM has been increased during Modification No. 5 (the means of passing data between the assembly language executive and the Fortran subroutines and functions). In writing the actual Fortran programs some variables that were used as dummy variables in the original software were moved to common in order to minimize the total number of bytes used in the RAM for the new programs THKFOR, EMAFOR and IDAFOR.

After debugging and testing all of the modifications and additions to the programs made during this Modification No. 5, it was found that most of the memory is utilized with only 19 bytes free in the 2K byte RAM and 386 bytes free in the 16K byte PROM.

All of the software for the improved SCI is included in Appendix 2. This is a detailed listing of all assembly language and Fortran language programs which includes the original BC/SCI set plus the modifications and additions made during this Modification No. 5.

2.D Test Program

The test program concluded during Modification No. 5 consisted of a series of discharge tests on battery packs and a variety of absolute and comparative tests to evaluate the performance of the parameter adaptor algorithms and programs.

2.D.1 Battery Discharge Tests

During Modification No. 5 a continuous test program was conducted exercising a 6-cell battery module with a variety of discharge profiles. The battery module consisted of two Gould PB-220 golf cart batteries. Discharge profiles included mostly constant power discharges mixed with some SAE 227a, schedule D driving cycle tests. The battery data recorded for each test consisted of voltage, current, temperature and time. Most battery tests were terminated with a constant power discharge at the 185 W/cell rate (10kW for a 54 cell battery module). This series of tests exercised the battery module from a brand new state down to an "aged" condition of less than one-half original capacity. The power levels, recharge percentage and battery temperatures for this test series are given in Table 2.D.1. It is important to note that the recharge percent was varied considerably, as wac the temperature, in order to provide more challenging test conditions for the adaptor algorithms.

Table 2.D.1

ADAPTOR ALGORITHM TEST CONDITIONS

TEST SEQUENCE NUMBERS	CONSTANT POWER LEVEL	RECHARGE % (see note below)	BATTERY TEMPERATURE (average)
1 - 6	185 W/cell	104%	21C
7 - 11	185 W/cell	100%	21C
12 - 21	185 W/cell	104%	21C
22 - 26	185 W/cell	102%	21C
27 - 31	185 W/cell	100%	21C
32 - 36	185 W/cell	104%	25C
37 - 46	185 W/cell	102%	25C
47 - 51	185 W/cell	108%	18C
52 - 54	185 W/cell	108%	29C
55 - 64	185 W/cell	108%	21C
65 - 70	185 W/cell	108%	50C
71 & 72	185 W/cell	108%	10C
73 & 74	50 W/cell	108%	10C
75 & 76	250 W/cell	108%	10C
77 & 78	50 W/cell	108%	35C
79 & 80	250 W/cell	108%	35C
81 - 84	185 W/cell	108%	25C
85 - 90	185 W/cell	108%	20C
91	185 W/cell	108%	33C
92	185 W/cell	115%	25C
93 - 106	185 W/cell	100%	25C

1. In addition to the normal recharges shown above, equalization charges were given of between 10 A-hrs. and 20 A-hrs. after every 500 A-hr. of cummulative discharging.
2. These tests were all performed on battery module # JPL 030/031 and represent a relatively contiguous aging history of that module.

2.D.2 Adaptor Concept Testing and Algorithm Testing

In addition to the battery discharge test data described in Section 2.D.1, Gould's extensive library of discharge data (accumulated over the past four years) was used to test both adaptor concepts and algorithms.

The testing performed at Gould during the original contract effort (and since at JPL) indicated that the basic State-Of-Charge (SOC) algorithm included in the BC/SCI was capable of +0, -10% accuracy when equipped with accurate battery parameters. Thus the basic premise of the test program of Modification No. 5 was to accept the SOC algorithm as a standard and to test the performance of the adaptor concepts and algorithms using that SOC algorithm.

The original adaptor algorithm described in Section 2.B.2.a was tested extensively on Gould's library of battery discharge data. It was found that its performance was reasonable at adapting the parameters in the middle zones of (I,T) space. However, at high temperatures the performance was poor. Nevertheless, the test data from this original adaptor algorithm provided a means of comparison for the improved adaptor concept.

The improved adaptor concept as defined in Section 2.B.2.b was tested on the same data base as was the original adaptor algorithm. The new adaptor concept was found, for the most part, to be superior to the original one. With that knowledge, the improved adaptor algorithm was developed and tested on, once again, the same data base.

The new data collected during Modification No. 5 (described in Section 2.D.1) would provide the most convincing test for the adaptor algorithms. Using a large minicomputer, the SOC algorithm used the recorded battery data to calculate the SOC. During all constant power intervals of each data record, the calculated SOC was compared to the measured SOC and an RMS error was calculated for the predictions. Figures 2.D.1 through 2.D.3 show a plot of the calculated SOC and the measured SOC for the:

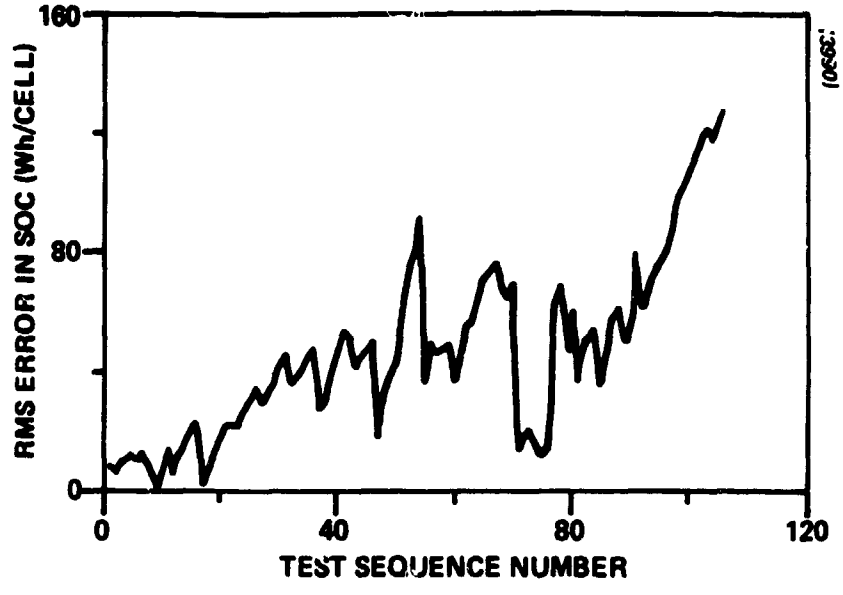


Figure 2.D.1 State of charge (SOC) algorithm performance with no parameter adaptation.

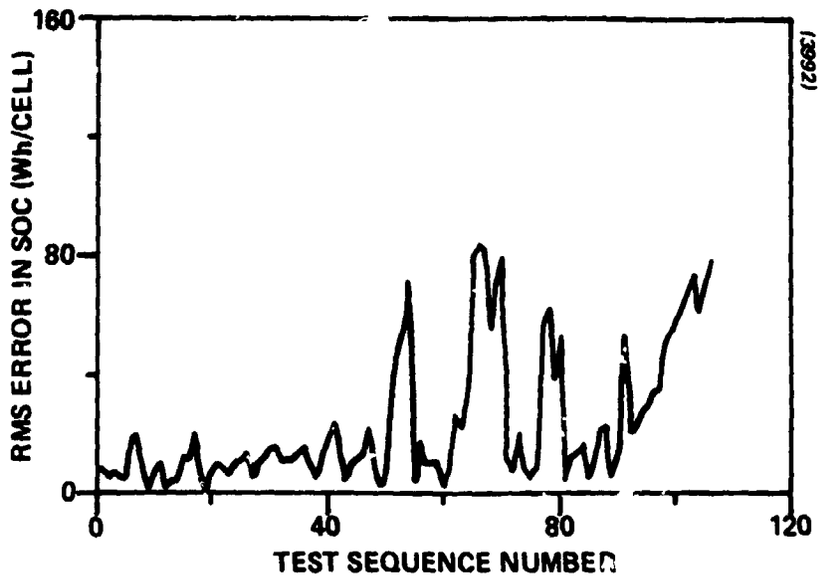


Figure 2.D.2 State of charge (SOC) algorithm performance with original parameter adaptor algorithm.

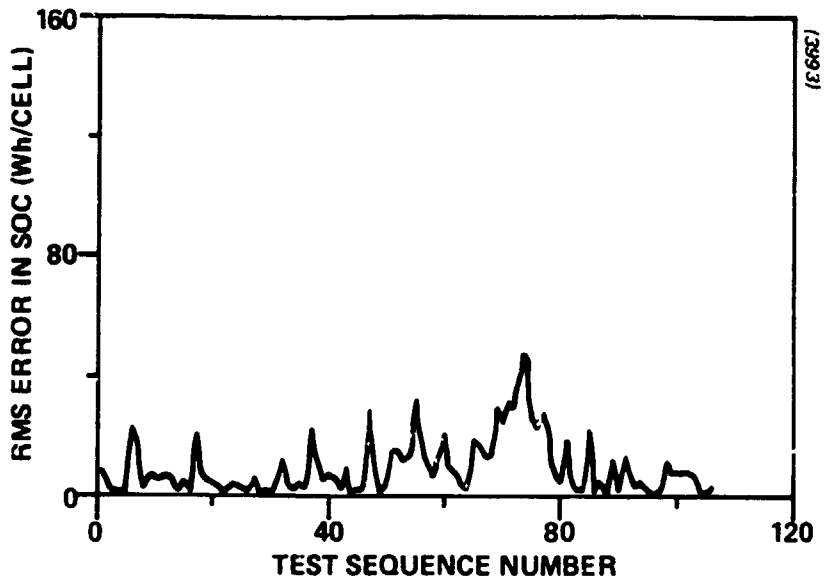


Figure 2.D.3 State of charge (SOC) algorithm performance with improved parameter adaptor algorithm.

1. SOC algorithm with no parameter adaptation.
2. SOC algorithm with the original parameter adaptor algorithm.
3. SOC algorithm with the improved parameter adaptor algorithm.

The RMS error in SOC is given in watt hours per cell. These battery modules started out with a capacity of a nominal 200 watt hours per cell, thus the approximate percent error in SOC can be read from the plots by dividing the RMS error by the number 2.

The failure of the original adaptor in predicting aging at extremes of temperature and current can be seen from Figure 2.D.2 (with the aid of Table 2.D.1). Test sequence numbers one through 64 were preformed at relatively nominal temperature and currents. Test sequence numbers 65 through 70 were performed at 50C. Since the original adaptor algorithm did not proportionally "age" or adapt in zones outside the ones experienced in previous operation, the resulting SOC error was high.

It can be seen from Figure 2.D 3 that the improved adaptor performed well for all conditions except the extreme of both low temperature and low current. The error, however, is at least conservative and would not yield an SCI reading that would result in the EV driver being stranded. Figure 2.D.4 traces the history of the parameter Q2 throughout the adaptation using the improved adaptor algorithm.

Convergence testing was performed on the improved adaptor algorithm. The results shown in Figures 2.D.5 and 2.D.6 indicate excellent stability with the parameter Q2 converging on a final value in five or less runs of the adaptor.

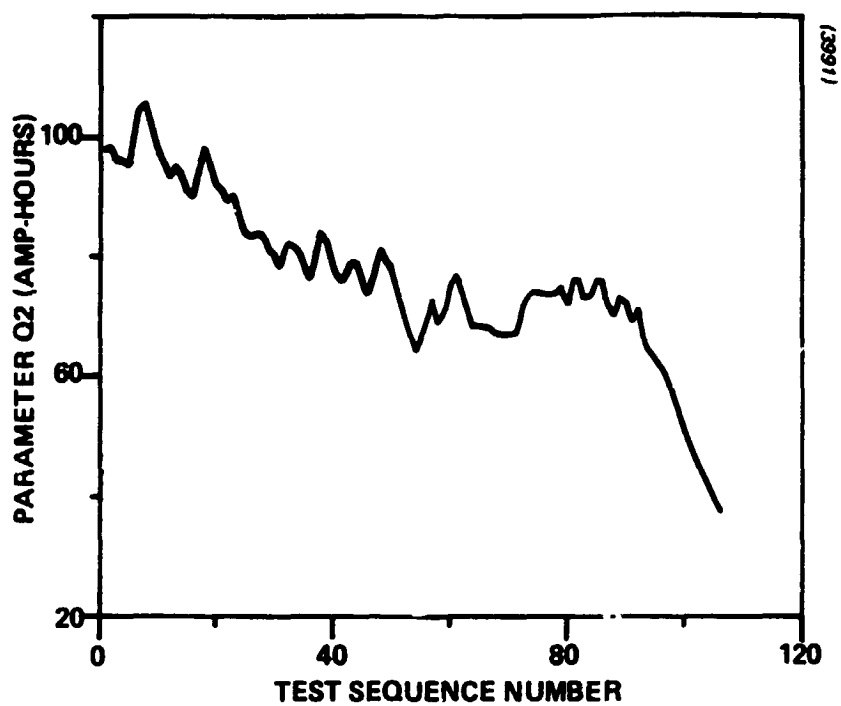


Figure 2.D.4 Battery parameter Q2 as adapted by the improved adaptor algorithm.

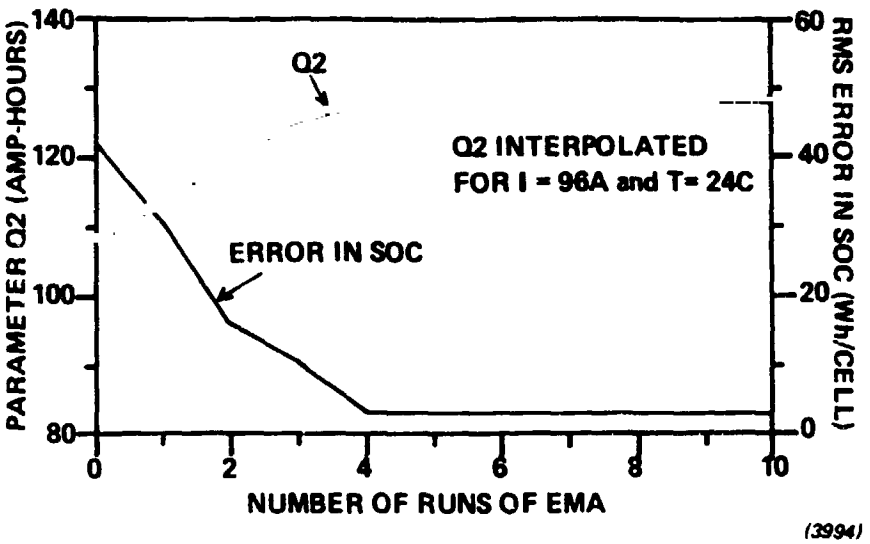


Figure 2.D.5 Convergence of improved adaptor when run successively on data file where Q2 is initially too low.

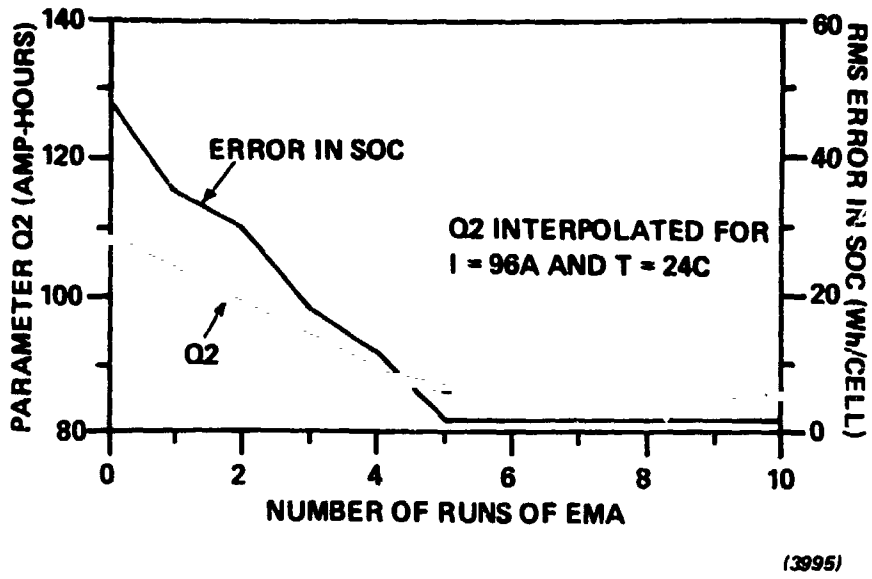


Figure 2.D.6 Convergence of improved adaptor when run successively on data file where Q2 is initially too high.

3.0 Conclusions and Recommendations

The improved SCI system developed during Modification No. 5 of this contract successfully fulfilled the target performance goals. The improved battery parameter adaptor will track the aging of the battery with a high degree of confidence. The values installed in the starting battery parameter array do have to be qualified (as indicated in the procedure given in Table 2.B.1 of this report) to insure SOC accuracy. Furthermore, the battery charger and SCI interface "handshaking" communications must be maintained to allow proper operation of the SCI.

Some recommendations are suggested for future high performance EV state-of-charge indicators:

1. Any interface with an external battery charger should be controlled by the microcomputer in the improved SCI. It already performs these functions and does them in a sequence that insures proper operation of the SCI.

2. The accuracy of the SCI could be improved further by increasing the data collecting and processing capability of the present SCI hardware. This could be accomplished by using a larger RAM.

3. If it is desired to have the SCI perform any additional functions, it may be mandatory to have both a larger RAM and PROM.

4. To afford the most accurate SCI readings over an extended period of time, it is recommended that the EV be driven at a constant speed for at least a 20 minute period once per week. This will (usually) insure the operation of the EMA subroutine of the parameter adaptor.

4.0 References

1. T.S. Latos, "A Battery Charger and State-of-Charge Indicator," Final Report, April, 15, 1984, DOE/CS 54209-16 or JPL Report #9950-900, Contract No. 955782 performed for Jet Propulsion Laboratory, California Institute of Technology.

2. H.L. Martin, "External Model for Performance Prediction of Lead-Acid Batteries in Electric Vehicle Usage--A Dynamic System Approach," Electric and Hybrid Vehicle Systems Development Laboratory 79-1, Purdue University, April 1979.

3. C.M. Shepherd, "An Equation Characterizing the Discharge of a Battery," J. Electrochem. Soc. 112 (1965), 657-664.

4. C. Daniel and F. Wood, "FITTING EQUATIONS TO DATA," John Wiley & Sons, Inc., New York, New York, 1971.

APPENDIX 1

Alphabetical Glossary of BC/SCI FORTRAN Modules

Alphabetical Glossary of BC/SCI FORTRAN Modules

AVGFOR - This subroutine performs the required averaging of data for time constants greater than thirty seconds in duration. Battery current and temperature are averaged over one battery time constant (6 min.), while vehicle speed and power are averaged over thirty seconds. Proper scaling to common engineering units is also performed by this routine.

BATMOD - This function models the battery in increments of time using the input parameters as a starting point and iteratively removes energy at constant power until the cutoff voltage is reached. The module is called with arguments for the present current, temperature and state (amp-hours) of the battery, in addition to the desired values for the discharge power level and final cutoff voltage. The simulation iterates until the predicted voltage is less than the desired cutoff voltage. The function returns to the calling program with a value for the time (in hours) to cutoff.

CHGFOR - The charge monitor subroutine controls the BC/SCI operation during the charge cycle. The routine calculates the charge required to recharge a battery for a given temperature and depth of discharge. It determines the appropriate voltage limit based upon electrolyte temperature and whether equalization is required. Charge acceptance and state-of-charge functions are performed by this program. The average voltage prediction error is updated on a daily basis.

DATFOR - This subroutine determines the validity of the data that was recorded during the discharge monitor. If at least four data records have no regeneration and do have power constant to within 10%, then the subroutine returns to THKFOR with the valid data flag set along with flags for the initial valid data record and the most recent valid data record.

DISFOR - The discharge monitor tracks parameters during a discharge and determines the battery state-of-charge for both the standard and arbitrary rates. Amp-hour meter compensation is also provided by comparing the known voltage with the predicted values. This error signal is appropriately "weighted" with a confidence factor. An average voltage prediction error is

updated each loop through the discharge monitor. After the battery is discharged approximately 50%, discharge data is recorded for use in the think mode.

EMAFOR - This subroutine is called by THKFOR if the data valid flag has been set. It adapts the battery parameter Q2 by minimizing an approximate integral squared error (in battery "impedance") through successive perturbations of the interpolated value of Q2. Then each value of Q2 in the parameter array is changed proportionally.

EVALZD - This function calculates the battery parameter values from a two dimensional table. Using the indexes and fractions for each of the two dimensions of the battery parameter table, a linear interpolation is made to determine the actual value for a given temperature and current. This general approach allows the function to be used for all three battery parameters (R1, R2, Q2) using appropriate arguments.

FDELTA - The function calculates the position (fractional distance) of a given value between the two most adjacent elements in a list.

IDAFOR - This subroutine is called by THKFOR if the data valid flag is not set. It provides an incremental default "aging" empirical estimate for the parameter Q2 which is proportional to the total charge removed from the battery.

INIFOR - The initialization subroutine initializes all parameters normally stored in Fortran common area (RAM). These parameters include the I-T table of R1, R2 and Q2 determined for a set of 54-Gould PB 220 lead-acid cells. Fortran scaling factors normally stored in random access memory are also initialized by this routine. If requested this program will also initialize the amp-hour meter using the equilibrium voltage and temperature as a direct determination for the battery's state-of-charge.

RSTFOR - The rest monitor subroutine uses the battery voltage and temperature to determine a correction factor for the system amp-hour meter.

TEMPFN - This fixed shaped function is evaluated for a specific plateau and valley over a 40 C temperature range. The "V" shaped function is centered at 27.5 C and spans ± 20 C.

THKFOR - This is the main subroutine for the think mode or battery parameter adaptor. It first calls the DATFOR subroutine to perform the data validity test. Then either EMAFOR or IDAFOR is called to accomplish parameter adaptation.

VDROP - This function calculates the internal voltage term for the battery model's impedance. This factor is based upon the battery parameters (R1, R2, Q2) and present conditions (Q, I). The answer is scaled to a volts/cell basis.

VEQ - This function calculates the equilibrium voltage based upon battery state-of-charge and temperature. The calculated answer is scaled to volts per cell.

ZONE - This subroutine controls the table search and interpolation of the battery parameters as a function of current and temperature. The boundary values for the I-T matrix are defined by the subroutines.

ZRQQ1 - This function calculates the portion of the battery impedance term which is dependent upon state-of-charge. An upper limit is imposed for the maximum value for this term.

APPENDIX II

BS/SCI Software Listings

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```
00001   0010          NAM    BCSCI1
00002   0012          OPT    REL,CRE,P=58,G,LLE=120
00003   0014          TTL    ENGINEERING PROTOTYPE - VERSION 1.1 EXECUTIVE
00004   0016 *
00005   0018 *       3/5/84 ASSEMBLY DATE : F.C.D.
00006   0020 *
00007   0022 *      DISK #118
00008   0024 *      BCSCI2 .SA  SOURCE FILE
00009   0026 *      BCSCI2 .RO  OBJECT FILE
00010   0028 *      BCSCI2 .LO  MEMORY IMAGE FILE
00011   0030 *
00012   0032 PROM    EQU     100       PROGRAM VERSION 1.10 IN PROM
00013   0034 *
00014   0036 *      SSTACK=$00-FF
00015   0038 *      USTACK=$100-11F
00016   0040 *      BSCT= $120-1BF     (SET TO $20)
00017   0042 *      CSCT= $200-2FF
00018   0044 *      DSCT= $300-7FF
00019   0046 *      PSCT= $C000-DFFF & E000-FFFF
00020   0048 *
00021   0050          SPC     3
00022   0052 *
00023   0054 *      CMOS - RANDOM ACCESS MEMORY TC-5517AP $0000-07FF
00024   0056 *             NON-VOLATILE
00025   0058 *
00026   0060 SSTA    EQU     $FF       SYSTEM STACK AREA
00027   0062 USTAC   EQU     $11F      USER STACK AREA
00028   0064 BSCT    EQU     $01       PAGE #1 DIRECT MODE ADDRESSING
00029   0066 SPAD    EQU     $120      SCRATCH PAD AREA - AND FLAG STORAGE
00030   0068 CBLK    EQU     $200      COMMON BLOCK VARIABLE STORAGE
00031   0070 CBLKZ   EQU     $220      COMMON BLOCK ZERO PRESET
00032   0072 GLOBAL  EQU     $300      GLOBAL DATA AREA
00033   0074 RAMS    EQU     $000      FIRST RAM MEMORY LOCATION
00034   0076 RAME    EQU     $7FF      LAST RAM MEMORY LOCATION
00035   0078          SPC     3
00036   0080          ASCT
00037   0082          ORG     $2000
00038   0084 *
00039   0086 *      HARDWARE EQUATES
00040   0088 *
00041   0090 *       REAL TIME CLOCK - NATIONAL MM5016N $E000-$201F
00042   0092 *
00043   0094 *      COUNTERS - BCD CODED
00044   0096 *
00045   0098 RTCCTS  EQU     *         90   THOUSANDTHS OF SECONDS
00046   0100 RTCCHS  EQU     *+1       99   HUNDREDTHS & TENTHS OF SECONDS
00047   0102 RTCCS   EQU     *+2       59   SECONDS
00048   0104 RTCCM   EQU     *+3       59   MINUTES
00049   0106 RTCCH   EQU     *+4       23   HOURS
00050   0108 RTCCDW  EQU     *+5       07   DAY OF WEEK
00051   0110 RTCCDM  EQU     *+6       31   DAY OF MONTH
00052   0112 RTCCMO  EQU     *+7       12   MONTH
00053   0114 *
00054   0116 *      LATCHES - BCD CODED
00055   0118 *
00056   0120 RTCLTS  EQU     *+8       THOUSANDTHS OF SECONDS  90
00057   0122 RTCLHS  EQU     *+9       HUNDREDTHS & TENTHS OF SECONDS  99
00058   0124 RTCLS   EQU     *+10      SECONDS  59
```

```
00059   0126 RTCLM  EQU    *+11      MINUTES  59
00060   0128 RTCLH  EQU    *+12      HOURS  29
00061   0130 RTCLDW EQU    *+13      DAY OF WEEK  07
00062   0132 RTCLDM EQU    *+14      DAY OF MONTH  30
00063   0134 RTCLMO EQU    *+15      MONTH  10
00064   0136 *
00065   0138 *      INTERRUPT CONTROL & STATUS , ONCE EVERY .
00066   0140 *                MONTH, WEEK, DAY, HOUR, MIN. , SEC. , .1SEC. , COMP
00067   0142 *                  D7     D6    D5    D4    D3    D2     D1     D0
00068   0144 *
00069   0146 RTCISR EQU    *+16      INTERRUPT STATUS REGISTER ( READ )
00070   0148 RTCICR EQU    *+17      INTERRUPT CONTROL REGISTER ( WRITE ) 1 ENABL
00071   0150 *
00072   0152 *      RESET LATCHES & COUNTERS
00073   0154 *       MONTH,DAY OF MONTH,DAY OF WEEK,HOURS,MIN. ,SEC. ,. 01&. TSEC , .
00074   0156 *         D7       D6            D5        D4   D3   D2      D1
00075   0158 *
00076   0160 RTCCRE EQU    *+18      COUNTER RESET
00077   0162 RTCLRE EQU    *+19      LATCH RESET
00078   0164 *
00079   0166 *      STATUS - D0=1 COUNTER ROLLOVER
00080   0168 *
00081   0170 RTCSR  EQU    *+20      STATUS REGISTER
00082   0172 *
00083   0174 *      SYNCHRONIZE - RESET THOUSANDTHS OF SEC.,HUNDREDTHS & TENTH. .
00084   0176 *                    & SEC. COUNTER
00085   0178 *
00086   0180 RTCGO  EQU    *+21      RESET COUNTER "GO" COMMAND
00087   0182 *
00088   0184 *      STANDBY INTERRUPT OUTPUT ENABLE D0=1
00089   0186 *
00090   0188 RTCSBY EQU    *+22      STANDBY INTERRUPT
00091   0190 RTCTST EQU    *+23      TEST MODE
00092   0192 *
00093   0194        SPC    3
00094   0196        ORG    $4000
00095   0198 *
00096   0200 *      PARALLEL INTERFACE ADAPTER - MC 6821  $4000-$4003
00097   0202 *
00098   0204 PIA1AD EQU    *         DATA DIR. REGISTER - DISPLAY CONTROL DEV. S
00099   0206 PIA1AC EQU    *+1       CONTROL REGISTER - SYNC : IRQ
00100   0208 PIA1BD EQU    *+2       DATA DIRECTION REGISTER - CMOS DATA BUS
00101   0210 PIA1BC EQU    *+3       CONTROL REGISTER - FIRQ
00102   0212        PAGE
00103   0214 *
00104   0216 *      MULTIPLEXER ADDRESSES
00105   0218 *       (LABEL)  - INDICATES LABLE'S MUX ADDRESS
00106   0220 *
00107   0222 AI     SET    0
00108   0224 *
00109   0226 *      SINGLE ENDED ANALOG INPUTS
00110   0228 *
00111   0230 BIPO   EQU    $80       BIPOLAR INPUT FLAG
00112   0232 *
00113   0234 TBAT.  SET    AI        BATTERY TEMPERATURE
00114   0236 TAMB.  SET    AI+1      AMBIENT TEMPERATURE
00115   0238 TFET.  SET    AI+2      FET TEMPERATURE
00116   0240 TENC.  SET    AI+3      ENCLOSURE TEMPERATURE
```

```
00117   0242 ASI4.   SET    AI+4      UNUSED
00118   0244 TREF.   SET    AI+5      REFERENCE TEMPERATURE
00119   0246 ILINE.  SET    AI+6      AC LINE CURRENT
00120   0248 TEST.   SET    AI+7      TEST VOLTAGE
00121   0250 *
00122   0252 *      DIFFERENTIAL ANALOG INPUTS
00123   0254 *
00124   0256 ADI16.  SET    AI+16     UNUSED
00125   0258 VBAT.   SET    AI+32     BATTERY VOLTAGE
00126   0260 IBAT.   SET    AI+48+BIPO BATTERY CURRENT
00127   0262 *
00128   0264 END.    SET    $FFFF     END OF SEQUENCE CHARACTER
00129   0266         SPC    3
00130   0268         DSCT
00131   0270 **
00132   0272 **     ABSOLUTE ADDRESS LABLES FOR FORTRAN/MPL ROUTINES
00133   0274 **     OFFSET (XXX$) OF ANALOG IDENTIFER INTO GLOBAL AREA
00134   0276 **
00135   0278 IBAT    RMB    2         .1 AMP / BIT
00136   0280 IBAT$   EQU    0
00137   0282 VBAT    RMB    2         .050 V / BIT -> .926MVPC/BIT
00138   0284 VBAT$   EQU    2
00139   0286 ILINE   RMB    2
00140   0288 ILINE$  EQU    4
00141   0290 TREF    RMB    2
00142   0292 TREF$   EQU    6
00143   0294 TBAT    RMB    2
00144   0296 TBAT$   EQU    8
00145   0298 TAMB    RMB    2
00146   0300 TAMB$   EQU    10
00147   0302 TENC    RMB    2
00148   0304 TENC$   EQU    12
00149   0306 TFET    RMB    2
00150   0308 TFET$   EQU    14
00151   0310 TEST    RMB    2
00152   0312 TEST$   EQU    16
00153   0314         SPC    3
00154   0316 **
00155   0318 **     BLANK COMMON SECTION FOR FORTRAN & MPL MODULES
00156   0320 **
00157   0322         CSCT
00158   0324 *     GLOBAL FLAGS : VOLATILE
00159   0326 FMODE   RMB    2         MODE CONT. 0-NORM. , 1-REQ CHNG. , NEG. CHNG.  GRA
00160   0328 WAKEF   RMB    2         BCD CODED (DAYS 0-30 , HOURS 0-24)
00161   0330 VLIM    RMB    2         VOLTAGE LIMIT SETPOINT
00162   0332 FINTF   RMB    2         FORTRAN INITIALIZATION FLAG
00163   0334 *     GLOBAL DATA INSTANTANEOUS . VOLATILE
00164   0336 XIBAT   RMB    2         DUPLICATION OF IBAT IN DSCT
00165   0338 XVBAT   RMB    2         DUPLICATION OF VBAT IN DSCT
00166   0340 TBATL   RMB    2         1C / BIT
00167   0342 SPEED   RMB    2         PULSES / 6 SEC.
00168   0344 *     GLOBAL DATA FILTER . VOLATILE (REAL DATA TYPE)
00169   0346 AMPSF   RMB    4         BATTERY CURRENT - AMPS
00170   0348 TEMPF   RMB    4         BATTERY TEMPERATURE - DEGREES C
00171   0350 PWRF    RMB    4         POWER OUT OF BATTERY - WATTS / CELL
00172   0352 SPDF    RMB    4         VEHICLE SPEED - PULSES / HOUR
00173   0354 *     GLOBAL DATA . NON-VOLATILE
00174   0356 AMPH    RMB    4         3.694XE-6 AHR / BIT -> .2421 A-HR/BIT (2BYTE
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00175   0358 QLAST   RMB    2          AMP-HOUR METER AFTER LAST CHARGE CYCLE
00176   0360 QABS    RMB    2          ABSOLUTE DISCHARGED AMP-HOURS SINCE EQUALIZI
00177   0362 *     GLOBAL VARIABLES : NON-VOLATILE
00178   0364 FRST    RMB    2          REST MODE FLAG
00179   0366 FCHG    RMB    2          CHARGE MODE FLAG "0"-NO "NEG"-YES "POS"-SPEI
00180   0368 FTHK    RMB    2          THINK MODE FLAG
00181   0370 FEQU    RMB    2          EQUALIZE STATUS FLAGS
00182   0372 RESET   RMB    2          NON-VOLATILE MEMORY RESET FLAG
00183   0374 SPDCAL  RMB    2          SPEED TRANSDUCER CALIBRATION FACTOR
00184   0376 DSOC    RMB    2          ALGORITHM S. O. C.  INFORMATION
00185   0378 DMILE   RMB    2          ALGORITHM MILEAGE INFORMATION
00186   0380 DISTIM  RMB    2          TIME SINCE LAST SELF-DISCHARGE
00187   0382 EQUTIM  RMB    2          TIME SINCE LAST EQUALIZE
00188   0384 CHGTIM  RMB    2          TIME SINCE START OF CHARGE CYCLE
00189   0385 IDATIM  RMB    2          TIME SINCE LAST DATA COLLECTION
00190   0386         SPC    3
00191   0388 **
00192   0390 **     GLOBAL VARIABLES NOT IN COMMON SECTION ( USED BY MFL )
00193   0392 **
00194   0394         XDEF   ILINE
00195   0396         XDEF   FCHGL,FFLT
00196   0398         XDEF   CCOUT,FFIN,SYIN
00197   0400         SPC    3
00198   0402 **
00199   0404 **     STARTING ADDRESSES FOR INTERRUPT VECTORS
00200   0406 **
00201   0408         XDEF   INIT,FIRQ,IRQ
00202   0410         SPC    3
00203   0412 **
00204   0414 **     EXTERNAL LABELS
00205   0416 **
00206   0418         XREF   CHGMFL
00207   0420         XREF   CHGFOR,DISFOR,RSTFOR,THKFOR
00208   0422         XREF   INIFOR
00209   0424         SPC    3
00210   0426 **
00211   0428 **     INSERT VARIABLE OFFSET FOR STORAGE LOCATION INTO 1'ST BYTE
00212   0430 **      OF ANALOG IDENTIFIER
00213   0432 **
00214   0434 IBAT.   SET    IBAT$**$100+IBAT.
00215   0436 VBAT.   SET    VBAT$**$100+VBAT.
00216   0438 ILINE.  SET    ILINE$**$100+ILINE.
00217   0440 TREF.   SET    TREF$**$100+TREF.
00218   0442 TBAT.   SET    TBAT$**$100+TBAT.
00219      4 TAMB.   SET    TAMB$**$100+TAMB.
00220      6 TENC.   SET    TENC$**$100+TENC.
00221   0448 TFET.   SET    TFET$**$100+TFET.
00222   0450 TEST.   SET    TEST$**$100+TEST.
00223   0452         PAGE
00224   0454 **
00225   0456 **     SYSTEM EQUATES
00226   0458 **
00227   0460 WARM    EQU    $AA55      VALID WARM-START FLAG
00228   0462 ROMS    EQU    $C000      START ADDRESS - ROM CHECK SUM TEST
00229   0464 ROME    EQU    $FFFF      END ADDRESS
00230   0466 *
00231   0468 *     PIA CONFIGURATION  DDR:DATA DIRECTION REG.  , PR:PERIPHERAL RE
00232   0470 *
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```
00233   0472 PIABDR EQU   %00110001 CB1(IN) NEG. - IRQ ENABLED; CB2(OUT)="0"; DDI
00234   0474 PIABPR EQU   %00110101                                          ;PR
00235   0476 PIAADR EQU   %00111011 CA1(IN) POS. - FIRQ ENABLED; CA2(OUT)="1"; DI
00236   0478 PIAAPR EQU   %00111111                                           ,PR
00237   0480 DSON   EQU   PIAAPR!.$F7 CA2 "0" DEVICE SELECT ACTIVE
00238   0482 DSOFF  EQU   PIAAPR   CA2 "1" DEVICE SELECT DISABLED
00239   0484         SPC   3
00240   0486 **
00241   0488 **     LOCAL VARIABLE STORAGE AREA - DIRECT MODE ADDRESSING
00242   0490 **
00243   0492         BSCT
00244   0494 PIAXAD RMB   1          DUMMY COPY OF PIA1AD (PIA REGISTER)
00245   0496 WARMF  RMB   2          WARM-START FLAG INDICATES WATCH-DOG RESET
00246   0498 FINT   RMB   1          INITIALIZATION FLAG
00247   0500 ISECC  RMB   1          INTERRUPT SECONDS COUNTER
00248   0502 MUXPTR RMB   2          MULTIPLEXIER TABLE POINTER
00249   0504 LVALUE RMB   2          TEMPORARY STORAGE OF LAST A/D VALUE
00250   0506 DVALF  RMB   1          DATA VALID FLAG
00251   0508 CADC   RMB   1          A/D CYCLE COUNTER
00252   0510 FAVG   RMB   1          DATA AVERAGE FLAG
00253   0512 FCAL   RMB   2          CALIBRATE MODE FLAG
00254   0514 SPDC   RMB   1          SPEED LOOP COUNTER
00255   0516 FSHUTD RMB   1          SHUTDOWN DELAY FLAG
00256   0518 FMODE2 RMB   1          ADC CHANGE FLAG
00257   0520 FMODE  RMB   2          POINTER FOR PRESENT OPERATING MODE
00258   0522 FFLT   RMB   1          FAULT DISPLAY FLAG "1" ACTIVE
00259   0524 FTST   RMB   2          TEST DISPLAY FLAG "1" ACTIVE,RUNNING
00260   0526 DDELAY RMB   1          FLAG USED TO HOLD SW1 REMOTE DISPLAY BUTTON
00261   0528 DEFLT  RMB   1          DEFAULT FLAG; FORCES DEFALUT SETTINGS
00262   0530 TSTPTR RMB   2          TEST ROUTINE TABLE POINTER
00263   0532 DFLTC  RMB   1          FAULT DELAY COUNTER
00264   0534 VFDATA RMB   6          TRANSMITTED PATTERN SEQUENCE
00265   0536 DSTAT  RMB   1          WARN,AC-ON,WATER,EQUALIZE, FAULT,BAR,NUM,GR
00266   0538 DSTATM RMB   1          DISPLAY STATUS MASK
00267   0540 DBAR   RMB   1          BINARY CODED BAR POSITION
00268   0542 DNUM   RMB   3          100'S     10'S      1'S
00269   0544 DIVW   RMB   2          DIVIDER WORSPACE
00270   0546 LOOPC  RMB   1          TRANSMIT LOOP COUNTER
00271   0548 BITC   RMB   1          TRANSMIT BYTE COUNTER
00272   0550 DISAF  RMB   1          POWER STAGE DISABLE FLAG
00273   0552 FPIN   RMB   2          FRONT PANEL INPUTS
00274   0554 SYIN   RMB   1          SYSTEM INPUTS
00275   0556 .AXIN  RMB   2          AUX. INPUTS
00276   0558 CCOUT  RMB   1          CHARGER CONTROL OUTPUTS
00277   0560 .FPOUT RMB   2          FRONT PANEL OUTPUTS; MASK
00278   0562 .AXOUT RMB   1          AUXILIARY OUTPUTS
00279   0564 CHGF   RMB   1          CHARGE FLAG & DELAY COUNTER
00280   0566 FCHGL  RMB   1          CHARGE INDICATOR
00281   0568 FWARN  RMB   1          WARNING INDICATOR
00282   0570 FFLASH RMB   1          FLASH COUNT
00283   0572 FLASHV RMB   1          VFD FLASH
00284   0574 FLASHL RMB   1          LED FLASH
00285   0576         SPC   3
00286   0578 **
00287   0580 **     LOCAL VARIABLE STORAGE AREA - NON-VOLATILE
00288   0582 **
00289   0584         DSCT
00290   0586 EDELAY RMB   2          ELECTROLYTE DELAY COUNT
```

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```
00291   0588 *
00292   0590 *     PROM IDENTIFIER BYTES
00293   0592 *
00294   0594          PSCT
00295   0596 ID       FCB     PROM      PROM I.D. BYTES VERSION #
00296   0598          FCB     $12       PROM SEQUENCE # ( e.g. 1'ST OF 2 PROMS )
00297   0600 CKSUM    FCB     $FF       CHECK SUM TEST BYTE
00298   0602          PAGE
00299   0604 **
00300   0606 **
00301   0608 **     HARDWARE INITIALIZATION SEQUENCE - RESET
00302   0610 **
00303   0612 **
00304   0614 INIT     ORCC    #$50      MASK INTERRUPTS (SWI RE-ENTRY)
00305   0616          LDS     #SSTACK   INITIALIZE SYSTEM STACK POINTER
00306   0618          LDU     #GLOBAL   INITIALIZE GLOBAL POINTER
00307   0620          LDA     #BSCT
00308   0622          TFR     A,DP      INITIALIZE DIRECT PAGE REGISTER
00309   0624 *
00310   0626          LBSR    PIAINT    INITIALIZE PIA
00311   0628 *
00312   0630 *     POWER-UP OR WATCH-DOG RESET
00313   0632 *
00314   0634          LDA     .AXOUT    NORMAL POWER-UP RESET? HOLD OFF
00315   0636          BPL     INIT1     YES
00316   0638          LDD     WARMF     WARM-START FLAG
00317   0640          CMPD    #WARM     VALID
00318   0642          LBEQ    WSTART    YES, JUMP TO WARM START ENTRY POINT
00319   0644 *
00320   0646 *     NORMAL START-UP : RUN COMPLETE DIAGNOSTICS & INITIALIZE SYSTE
00321   0648 *
00322   0650 *     INITIALIZE SYSTEM FLAGS & SCRATCH PAD AREA
00323   0652 *
00324   0654 INIT1    LDX     #SPAD+1   LOWER ADDRESS LIMIT +1 (NOT PIAXAD)
00325   0656 INIT1A   CLR     0,X+      CLEAR BYTE
00326   0658          CMPX    #CELKZ    UPPER ADDRESS LIMIT
00327   0660          BLO     INIT1A
00328   0662          LDA     #$82
00329   0664          STA     .AXOUT    SET HOLD, DC FAULT, RESET I/O FAULT  CLR FA
00330   0666          CLR     CCOUT     DISABLE POWER STAGE
00331   0668          LDD     #$0F0F
00332   0670          STD     FPOUT     SET  FAULT, CHG. EQU. WATER (LEDS)
00333   0672          LBSR    DOUT
00334   0674          LBSR    DINPUT    INIALIZE INPUT SWITCH POSITIONS
00335   0676 *
00336   0678 *     RUN SYSTEM DIAGNOSTIC - uC
00337   0680 *
00338   0682          LBSR    PIATST    RUN DIAGNOSTICS ON PIA
00339   0684          LBSR    ROMTST    TEST PROGRAM MEMORY - BYTE CHECKSUM
00340   0686          LBSR    WDOG      RESET WATCH-DOG TIMER
00341   0688          LBSR    RAMTST    TEST VARIABLE MEMORY - BIT TOGGLE
00342   0690          LBSR    CLKTST    TEST REALTIME CLOCK
00343   0692 *
00344   0694          LDA     RTCISR
00345   0696          BITA    #$01      TIMER COMPARE - WAKE-UP MODE
00346   0698          BEQ     INIT1B
00347   0700          LDA     RTCLDM
00348   0702          CMPA    #$02      1 DAY OR LONGER WAKE-UP PERIOD
```

```
00349   0704          BHS     INIT1B   YES: DON'T RUN FORRST SUBROUTINE
00350   0706          LDX     #-1
00351   0708          STX     FRST     SET FLAG FOR REST MODE
00352   0710 INIT1B   CLR     RTCSBY   DISABLE STANDBY INTERRUPT
00353   0712 *
00354   0714          LBSR    TIMEA    CORRECT TIME COUNTERS FOR SHUTDOWN PERIOD
00355   0716          LDD     EQUTIM
00356   0718          CMPD    #5040    TEST FOR 7 DAYS
00357   0720          BLO     INIT1C   NO: DON'T EQUALIZE
00358   0722          LDD     #-1
00359   0724          STD     FEQU     SET EQUALIZE FLAG
00360   0726          STD     FCHG     SET CHARGE REQUEST FLAG
00361   0728 *
00362   0730 *     INITIALIZE CONTROL FLAGS
00363   0732 *
00364   0734 INIT1C   LDD     #-1
00365   0736          STA     FINT     SET INITIALIZATION FLAG
00366   0738          STD     FMODE    SET MODE CHANGE
00367   0740          LBSR    DINPUT   INPUT SWITCH POSITIONS-CHANGE FLAG INITIZAT
00368   0742 *
00369   0744          LDA     FPIN     CHECK FOR SPECIAL CHARGE CYCLE REQUEST
00370   0746          BITA    #$80     EQUALIZE BUTTON DEPRESSED?
00371   0748          BEQ     INIT2    NO
00372   0750          LDD     #1       SET SPECIAL CYCLE REQUEST FLAG
00373   0752          STD     FCHG
00374   0754 *
00375   0756 INIT2    LBSR    SMODE    DETERMINE REQUESTED OPERATING MODE
00376   0758 *
00377   0760          LBSR    PWRTST   TEST NON-VOLATILITY OF RAM
00378   0762 *
00379   0764          TST     DEFLT    RAM DATA VALID
00380   0766          BEQ     INIT2B   YES
00381   0768 *
00382   0770          LDX     #CELKZ   1ST DATA LOCATION IN COMMON AREA
00383   0772 INIT2A   CLR     0,X+     ZERO DATA STORAGE AREA
00384   0774          CMPX    #RAME    LAST MEMORY LOCATION+1
00385   0776          BLO     INIT2A   NOT YET
00386   0778 *
00387   0780 *      RUN DIAGNOSTICS - SIGNAL CONDITIONING (I/O)
00388   0782 *
00389   0784 INIT2B   LDA     #$84
00390   0786          STA     AXOUT    SET:HOLD,I/O FAULT,, RESET,DC FAULT, LPS FA
00391   0788          LBSR    DOUT2    UPDATE AUX OUTPUTS
00392   0790 *
00393   0792 *     INITIALIZE ADC FOR PROPER DIAGNOSTICS
00394   0794 *
00395   0796          CLR     RTCICR   INHIBIT TIMER INTERRUPTS
00396   0798          LDA     PIA1AD   CLEAR FIRQ FLAG
00397   0800          LDA     PIA1BD   CLEAR IRQ FLAG
00398   0802          LDX     PMODE
00399   0804          PSHS    X        SAVE NORMAL MODE POINTER
00400   0806          LDX     #TBLDIA
00401   0808          STX     PMODE    SET DIAGNOSTIC MODE
00402   0810          LDA     #$01
00403   0812          STA     FMODE2   FLAG MODE CHANGE TO ADC ROUTINE
00404   0814 INIT3    CWAI    #$EF     ENABLE IRQ
00405   0816          TST     FAVG     ALL DIAGNOSTIC INPUTS READ?
00406   0818          BEQ     INIT3    NO
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```
00407  0820          ORCC   #$50      MASK ALL INTERRUPTS
00408  0822          LDB    FFLT      CHECK FOR ADC FAULTS
00409  0824          BEQ    INIT4     NONE
00410  0826          LBSR   ERROR     DISPLAY FAULT
00411  0828 INIT4    PULS   X
00412  0830          STX    PMODE     RETRIEVE NORMAL MODE POINTER
00413  0832          INC    FMODE2    SET MODE CHANGE FLAG
00414  0834          CLR    DVALF     DATA NOT VALID
00415  0836 *
00416  0838          LBSR   ADCTST    TEST A/D CONVERTER ON KNOWN INPUT
00417  0840 *
00418  0842          LBSR   TMPTST    TEST THERMISTORS FOR OPENS OR SHORTS
00419  0844 *
00420  0846          LDA    #$80
00421  0848          STA    AXOUT     SET:HOLD ; RESET:BOARD FAULT LED'S
00422  0850          LBSR   DOUT2
00423  0852 *
00424  0854 INIT5    LDD    #$0
00425  0856          STD    FPOUT     RESET ALL FRONT PANEL LED'S
00426  0858          LBSR   DOUT1
00427  0860 *
00428  0862          CLR    FINT      INIALIZATION COMPLETE
00429  0864 *
00430  0866 *      WARM-START ENTRY POINT
00431  0868 *
00432  0870 WSTART   LDA    PIA1BD    CLEAR IRQ FLAG
00433  0872          LDA    RTCISR    CLEAR PRIOR INTERRUPTS
00434  0874          LDA    PIA1AD    CLEAR FIRQ - FLAG
00435  0876          LDA    #$04
00436  0878          STA    RTCICR    SET TIMER INTERRUPT - 1 SEC.
00437  0880          LDD    #WARM
00438  0882          STD    WARMF     SET SYSTEM RUNNING CODE
00439  0884          ANDCC  #$AF      ENABLE FIRQ & IRQ
00440  0886          LDU    #USTACK   SET USER STACK FOR FORTRAN USE
00441  0888          SPC    3
00442  0890 **
00443  0892 **    INITIALIZE FORTRAN PROGRAMS
00444  0894 **       AFTER A POWER LOSS OR SPECIAL REQUEST
00445  0896 **
00446  0898          LDD    FCHG
00447  0900          CMPD   #0
00448  0902          BGT    EXECI     REQUEST SPECIAL CHARGE CYCLE
00449  0904          TST    DEFLT
00450  0906          BEQ    EXEC
00451  0908 EXECI    JSR    INIFOR    RUN INITIALIZATION
00452  0910          CLR    DEFLT
00453  0912          SPC    3
00454  0914 **
00455  0916 **    FORTRAN ENTRY AND RETURN EXECUTIVE
00456  0918 **
00457  0920 EXEC     LDD    FMODE     MODE CHANGE GRANTED?
00458  0922          BNI    EXEC      YES - WAIT FOR EXECTUTIVE TO RECONIZE
00459  0924          TST    DVALF     DATA VALID FOR FORTRAN ROUTINE ?
00460  0926          BEQ    EXEC      NO - WAIT FOR MODE CHANGE TO BE COMPLETED
00461  0928          LDY    FMODE     DETERMINE SELECTED MODE
00462  0930          JSR    [FFOR,Y]  ENTER APPROPRIATE FORTRAN MODE ROUTINE
00463  0932          BRA    EXEC      SELECT NEW MODE
00464  0934          PAGE
```

```
00465    0936 **
00466    0938 **     INTERRUPT SERVICE ROUTINE : IRQ
00467    0940 **
00468    0942 **      TRIGGERED BY END OF CONVERSION SIGNAL FROM A/D CONVERTER
00469    0944 **
00470    0946 **
00471    0948 IRQ     LBSR   ACONV     SERVICE ADC , AVERAGE VALUES , CAL.  AMP-HOUI
00472    0950         TST    FINT      INITIALIZATION?
00473    0952         BNE    IRQ1      YES, RETURN
00474    0954 *
00475    0956         LBSR   DINPUT    READ DIGITAL INPUTS
00476    0958 *
00477    0960         LBSR   SMODE     SELECT PROPER OPERATING MODE
00478    0962 *
00479    0964         LBSR   INVSP     READ VEHICLE SPEED
00480    0966 *
00481    0968         LBSR   SAFETY    CHECK MISC.  FAULT CONDITIONS
00482    0970 *
00483    0972         LBSR   DISSEL    SELECT PROPER DISPLAY
00484    0974 *
00485    0976         LBSR   DOUT      OUTPUT DIGITAL INFORMATION
00486    0978 *
00487    0980         LBSR   CDISP     CONFIGURE VACUUM FLUORESCENT ELEMENTS
00488    0982 *
00489    0984         LBSR   VFDISP    TRANSMIT INFORMATION TO DISPLAY
00490    0986 *
00491    0988 IRQ1    LDA    RTCISR    ACKNOWLEDGE MISSED CLOCK INTERRUPT
00492    0990         RTI
00493    0992         SPC    6
00494    0994 **
00495    0996 **     INTERRUPT SERVICE ROUTINE : FIRQ
00496    0998 **
00497    1000 **       1/SEC.  TIMER - REAL TIME CLOCK
00498    1002 **
00499    1004 **
00500    1006 **
00501    1008 FIRQ    PSHS   A,B,X,Y   SAVE PRESENT STATE
00502    1010         LDA    PIA1AD    CLEAR FIRQ FLAG
00503    1012         LDA    RTCISR    ACKNOWLEDGE INTERRUPT
00504    1014         CMPA   #$04      TEST 1/ SEC
00505    1016         BEQ    FIRQ1     OK
00506    1018         LDB    #ERRCIO
00507    1020         STB    FFLT      SET FAULT CODE
00508    1022 FIRQ1   COM    FFLASH    TOGGLE FLASH BIT
00509    1024         LDA    ISECC     ADVANCE SECONDS COUNTER
00510    1026         INCA
00511    1028         CMPA   #120      WAIT 2 MINUTES
00512    1030         BLO    FIRQ2
00513    1032         LDD    #$01      SET FOR 1COUNT ADVANCE (2 MIN.)
00514    1034         LBSR   TIME      ADVANCE TIME LOCATIONS
00515    1036         CLRA             RESET COUNTER
00516    1038 FIRQ2   STA    ISECC
00517    1040         PULS   A,B,X,Y
00518    1042         RTI
00519    1044         PAGE
00520    1046 **
00521    1048 **     A/D CONVERTER SERVICE ROUTINE - INTERSIL 7109 ADC
00522    1050 **
```

```
00523    1052 **       2 BYTE READS   12 BIT MAGNITUDE VALUE , POLARITY , OVERRANG
00524    1054 **                            B11 - B0              B15         B14
00525    1056 **
00526    1058 **       CHECKS FOR OVERRANGE INPUTS : SETS VALUE TO FULL SCALE
00527    1060 **       & SETS FAULT FLAG FFLT TO APPROPRIATE ERROR CODE - ERROF.
00528    1062 **       CHECKS FOR INCORRECT POLARITY : SETS ERROR CODE - ERRNEG:
00529    1064 **       MUX SEQUENCE DEPENDENT ON TABLE LOOK-UP OF APPROPRIATE
00530    1066 **       MODE,
00531    1068 **            MUXCHG ; MUXDIS ; MUXRST ; MUXTHK
00532    1070 **
00533    1072 **       ROUTINE DETERMINES 2'S COMPLEMENT OF VALUE FOR NEGATIVE
00534    1074 **       POLARITY INDICATIONS BEFORE SAVING
00535    1076 **
00536    1078 **       PRESENT VALUE SAVED GLOBAL AREA POINTED TO BY UREG + VARIAE
00537    1080 **       OFFSET FOUND IN 1'ST BYTE OF VARIABLE IDENTIFIER
00538    1082 **       CONVERTER IS CONFIGURED TO CONVERT NEXT INPUT
00539    1084 **
00540    1086 **       CALCULATES AVERAGE OF 8 MEASUREMENTS WHEN FAVG SET
00541    1088 **
00542    1090 **       CALCULATES WEIGHTED AMP-HOURS FOR IBAT READINGS USING A/D
00543    1092 **       CYCLE RATE AS TIME BASE
00544    1094 **       NOTE  MODE CHANGE IS NOT COMPLETE UNTIL, FMODE2 = 0 & FAVG
00545    1096 **           THESE CONDITIONS WILL INSURE VALID DATA HAS BEEN SAVED
00546    1098 **           FOR EXTERNAL USE ;DVALF=1
00547    1100 **
00548    1102 ACONV  LDA     PIA1BD    CLEAR IRQ FLAG
00549    1104        LDU     #GLOBAL   SET U-REG AS GLOBAL POINTER
00550    1106        TST     FMODE2    CHANGE MODES ?
00551    1108        BEQ     ACON1     NO
00552    1110        CLR     FAVG      NO AVERAGING FOR ONE COMPLETE CYCLE
00553    1112        CLR     CADC      RESET CYCLE COUNTER
00554    1114        LBRA    ACONV7
00555    1116 ACON1  TST     FAVG      AVERAGING STARTED?
00556    1118        BEQ     ACON1A    NO
00557    1120        LDA     #$01
00558    1122        STA     DVALF     SET DATA VALID INDICATION
00559    1124 ACON1A LDA     #$01      LOW BYTE SELECT CODE
00560    1126        LBSR    INPUT
00561    1128        STB     LVALUE+1  SAVE 8 LSB
00562    1130        LDA     #$02      HIGH BYTE SELECT CODE
00563    1132        LBSR    INPUT
00564    1134        STB     LVALUE    SAVE 4 MSB + POLARITY + OVERFLOW
00565    1136 *
00566    1138        LDX     MUXPTR
00567    1140        PSHS    X         POSITION POINTER ON STACK FOR FUTURE REFERE
00568    1142 *
00569    1144 *      VERIFY OVERFLOW
00570    1146 *
00571    1148        LDA     LVALUE    RECALL LAST VALUE
00572    1150        TFR     A,B
00573    1152        ANDB    #$0F
00574    1154        STB     LVALUE    STRIP OFF POLARITY & OVERFLOW INFORMATION
00575    1156        BITA    #$10      TEST OVERFLOW BIT
00576    1158        BEQ     ACONV2    O.K.
00577    1160        LDY     #$0FFF
00578    1162        STY     LVALUE    SET MAX. VALUE
00579    1164        LDB     #ERROF
00580    1166        STB     FFLT      SET OVERFLOW ERROR CODE
```

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00581    1168 *
00582    1170 *      VERIFY PROPER POLARITY
00583    1172 *
00584    1174 ACONV2 BITA    #$80        TEST POLARITY
00585    1176        BNE     ACONV3      POSITIVE , O.K.
00586    1178        LDD     LVALUE
00587    1180        COMA
00588    1182        COMB
00589    1184        ADDD    #01         FORM 2'S COMPLEMENT
00590    1186        STD     LVALUE
00591    1188        CMPD    #-50        MORE THAN 50MV NEGATIVE
00592    1190        BGT     ACONV3      NO
00593    1192        LDB     1,X
00594    1194        BITB    #$80        BIPOLAR DESIGNATED INPUT
00595    1196        BNE     ACONV3      YES , CONTINUE
00596    1198        LDB     #ERRNEG
00597    1200        STB     FFLT        SET POLARITY ERROR CODE
00598    1202 *
00599    1204 ACONV3 LDY     LVALUE
00600    1206        TST     FAVG
00601    1208        BEQ     ACONV4      NO AVERAGING
00602    1210 *
00603    1212 *      AVERAGE DATA  (LVALUE + 7(OVALUE))/8
00604    1214 *
00605    1216        LDD     #$0703
00606    1218        STB     DIVW        PRE-SAVE DIVISOR 2^DIVW
00607    1220        PSHS    A           SET MULTIPIER FOR QMUL ROUTINE
00608    1222        LDA     [1,S]       RETRIEVE OFFSET TO VARIABLE STORAGE LOCATIO
00609    1224        LDD     A,U         FETCH PRIOR AVERAGE
00610    1226        LBSR    QMUL
00611    1228        LEAS    1,S         CLEAN UP STACK AFTER MULTIPLY
00612    1230        ADDD    LVALUE      ADD NEW CONTRIBUTION TO AVERAGE
00613    1232        LBSR    QDIV        QUICK DIVIDE BY 8
00614    1234 *
00615    1236        CMPD    LVALUE      CORRECT FOR AVERAGING OFFSETS
00616    1238        BEQ     ACON3B
00617    1240        BGT     ACON3A
00618    1242        ADDD    #$01
00619    1244        BRA     ACON3B
00620    1246 ACON3A SUBD    #$01
00621    1248 *
00622    1250 ACON3B TFR     D,Y         TEMPORARY HOLD AVERAGE VALUE
00623    1252 ACONV4 LDA     [0,S]       FETCH VARIABLE OFFSET
00624    1254        STY     A,U         SAVE NEW AVERAGE
00625    1256 *
00626    1258 *      CALCULATE AMP-HOURS IF NECESSARY
00627    1260 *
00628    1262        LDX     [0,S++]     RETRIEVE MUX POINTER
00629    1264        CMPX    #IBAT       CHECK FOR BATTERY CURRENT INPUT
00630    1266        BNE     ACONV5      NO
00631    1268        LDA     CADC
00632    1270        PSHS    A
00633    1272        LDD     LVALUE
00634    1274        LBSR    QMUL
00635    1276        LEAS    1,S         CLEAN UP STACK
00636    1278        BMI     ACON4A
00637    1280        LDX     #$0         SET BMSB FOR POS  NUMBER
00638    1282        BRA     *+5
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00639    1294 ACON4A LDX     #$FFFF    SET BMSB FOR NEG. NUMBER
00640    1296        ADDD    AMPH+2    ACCUMULATE RAW VALUE OF AMP-HOURS
00641    1298        STD     AMPH+2
00642    1290        TFR     X,D
00643    1292        ADCB    AMPH+1
00644    1294        ADCA    AMPH
00645    1296        STD     AMPH
00646    1298        CLR     CADC      RESET CYCLE COUNTER
00647    1300        BRA     ACONV6
00648    1302 *
00649    1304 *  LINEARIZE BATTERY THERMISTOR READING
00650    1306 *
00651    1308 ACONV5 CMPX    #TBAT.    BATTERY THERMISTOR INPUT
00652    1310        BNE     ACONV6    NO
00653    1312        LDX     #TBLTHE   SET TABLE POINTER
00654    1314        LDD     TBAT$,U   GET AVERAGED RAW VALUE
00655    1316        LBSR    LTBL      LINEARIZE SUBROUTINE
00656    1318        SUBD    #40       CORRECT FOR TABLE OFFSET
00657    1320        STD     TBATL     SAVE RESULTS
00658    1322 *
00659    1324 ACONV6 LDX     MUXPTR
00660    1326        LEAX    2,X       ADVANCE POINTER
00661    1328        INC     CADC      ADVANCE CYCLE COUNTER
00662    1330        LDD     0,X
00663    1332        CMPD    #END.     END OF TABLE
00664    1334        BNE     ACONV8    NO , CONTINUE
00665    1336 *
00666    1338        LDA     #$01
00667    1340        STA     FAVG      SET AVERAGE FLAG
00668    1342        STA     DVALF     SET DATA VALID FLAG
00669    1344 ACONV7 LDY     PMODE
00670    1346        LDX     ADC,Y     POINT TO 1'ST TABLE ENTRY
00671    1348 *
00672    1350 ACONV8 STX     MUXPTR    SAVE NEW POINTER VALUE
00673    1352        LDA     #0        MUX DEVICE SELECT CODE
00674    1354        LDB     1,X       READ NEW MUX ADDRESS
00675    1356        LBSR    OUTPUT    CONFIGURE A/D CONVERTER
00676    1358        CLR     FMODE2    MODE CHANGE COMPLETE
00677    1360 *
00678    1362 *  DUPLICATE ITEMS TO COMMON BLOCK FOR EXTERNAL ACCESS
00679    1364 *
00680    1366        LDD     IBAT      COPY BATTERY CURRENT
00681    1368        STD     XIBAT
00682    1370        LDD     VBAT      COPY BATTERY VOLTAGE
00683    1372        STD     XVBAT
00684    1374        RTS
00685    1376        PAGE
00686    1378 **
00687    1380 **     SELECT OPERATING MODE - SUBROUTINE
00688    1382 **
00689    1384 **       DETERMINES APPROPRIATE OPERATING MODE BASED UPON
00690    1386 **       DIGITAL INPUTS AT FFIN AND FRST AND TRANSFERS
00691    1388 **       CONTROL TO SPECIFIC ROUTINE.
00692    1390 **       IF NO VALID MODE DETERMINED FOR 3 CYCLES : SHUTDOWN
00693    1392 SMODE  CLR     FCAL      RESET CALIBRATE FLAG
00694    1394        CLR     FTST      RESET TEST FLAG
00695    1396        LDB     #$01
00696    1398        LDA     SYIN
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00697  1400          BITA   #$08     TEST MODE?
00698  1402          BNE    SMODE2   YES
00699  1404          BITA   #$04     CALIBRATE MODE?
00700  1406          BNE    SMODE1   YES
00701  1408          LDA    FPIN
00702  1410          ANDA   #$07
00703  1412          CMPA   #$00     TEST MODE?
00704  1414          BEQ    SMODE2   YES
00705  1416          CMPA   #$05     CALIBRATE MODE?
00706  1418          BNE    SMODE3   NO, CONTINUE
00707  1420 SMODE1   STB    FCAL     SET CALIBRATE FLAG
00708  1422          BRA    SMODE3
00709  1424 SMODE2   STB    FTST     SET TEST MODE FLAG
00710  1426 SMODE3   LDY    #$0      SET INVALID MODE FLAG
00711  1428          LDD    FRST     REST FLAG ACTIVE
00712  1430          BEQ    *+6      NO
00713  1432          LDY    #TBLRST  SET REST MODE
00714  1434          LDD    FTHK     THINK FLAG ACTIVE
00715  1436          BEQ    *+6      NO
00716  1438          LDY    #TBLTHK  SET THINK MODE
00717  1440          LDA    FPIN
00718  1442          BITA   #$08     AC-LINE ON
00719  1444          BNE    SMODE4   NO
00720  1446          LDX    FCHG     CHARGE CYCLE REQUESTED
00721  1448          BEQ    *+6      NO
00722  1450          LDY    #TBLCHG  SET CHARGE MODE
00723  1452 SMODE4   BITA   #$40     E.V. CONTROLLER ON
00724  1454          BNE    *+6      NO
00725  1456          LDY    #TBLDIS  SET DISCHARGE MODE
00726  1458          CLRA            RESET SHUTDOWN FLAG
00727  1460          LDB    #ERRSM1  SET ERROR CODE FOR POSSIBLE SHUTDOWN
00728  1462          TST    FINT     INITIALIZE SEQUENCE ?
00729  1464          BEQ    SMODE5   NO
00730  1466          CMPY   #$0      CHECK FOR VALID MODE
00731  1468          LBEQ   SHUTD    INITIALIZATION AND NO VALID MODE
00732  1470          STY    PMODE    SAVE SELECTED MODE
00733  1472          RTS             RETURN
00734  1474 *
00735  1476 SMODE5   CMPY   #$0      CHECK FOR VALID MODE
00736  1478          BNE    SMODE6   O.K.
00737  1480          LDX    PMODE
00738  1482          LBMI   SHUTD    MODE CHANGE COMPLETE AND NO NEW MODE
00739  1484          LDA    FSHUTD
00740  1486          INCA
00741  1488          CMPA   #225     DELAY SHUTDOWN FOR (30 SEC /  133)
00742  1490          LBHI   SHUTD    DELAY COMPLETED
00743  1492 SMODE6   STA    FSHUTD
00744  1494          CMPY   PMODE    CHECK LAST MODE
00745  1496          BEQ    SMODE8   SAME CONTINUE
00746  1498          LDX    PMODE
00747  1500          BNE    SMODE7   CHANGE ALREADY REQUESTED
00748  1502          LDX    #1
00749  1504          STX    PMODE    SET CHANGE REQUEST FLAG
00750  1506 SMODE7   BPL    SMODE9   REQUEST NOT YET ACKNOWLEDGED
00751  1508          LDA    #$01
00752  1510          STA    PMODE2   SET ADC CHANGE FLAG
00753  1512          CLR    DVALF    RESET DATA VALID FLAG
00754  1514          STY    PMODE    SET NEW MODE POINTER
```

```
00755   1516 SMODE8 LDX     #$0
00756   1518        STX     FMODE     RESET MODE CONTROL FLAG
00757   1520 SMODE9 LDY     FMODE     RETAIN PRIOR MODE
00758   1522        JMP     [0,Y]     RUN APPROPRIATE MODE SUBROUTINE AND RETURN
00759   1524        PAGE
00760   1526 *
00761   1528 *
00762   1530 *      CHARGE MODE - SUBROUTINE WRITTEN IN MPL : CHGMPL
00763   1532 *
00764   1534 *
00765   1536 CHARGE RTS
00766   1538 *
00767   1540 *
00768   1542 *      DISCHARGE MODE - SUBROUTINE CALLS FORTRAN AVGFOR TO FILTER
00769   1544 *                       BATTERY AND VEHICLE DATA DURING DISCHARGE
00770   1546 *
00771   1548 *
00772   1550 DISCHG TST     DVALF     DATA VALID
00773   1552        BNE     DISCH1    YES
00774   1554        LDD     #-1       SET INITIALIZATION FLAG FOR FORTRAN
00775   1556        BRA     DISCH2
00776   1558 DISCH1 LDD     FINTF
00777   1560        BMI     DISCH3    WAIT FOR INITIALIZATION TO ACKNOWLEDGE
00778   1562        ADDD    #01       INCREMENT DELAY COUNT
00779   1564 DISCH2 STD     FINTF
00780   1566 DISCH3 RTS
00781   1568 *
00782   1570 *
00783   1572 *      REST MODE - SUBROUTINE
00784   1574 *
00785   1576 *
00786   1578 REST   RTS
00787   1580 *
00788   1582 *
00789   1584 *      THINK MODE - SUBROUTINE
00790   1586 *
00791   1588 *
00792   1590 THINK  RTS
00793   1592        PAGE
00794   1594 **
00795   1596 **     VEHICLE SPEED INPUT & CALIBRATION SUBROUTINE
00796   1598 **        FCAL=1 FLAGS CALIBRATION REQUEST
00797   1600 **        FCAL+1=1 FLAGS CALIBRATION IN PROGRESS
00798   1602 **        CALIBRATION FACTOR = SPDCAL
00799   1604 **        SW1 STARTS AND ENDS CALIBRATION PROCEEDURE
00800   1606 **        OVER CALIBRATED MILE COURSE
00801   1608 **
00802   1610 INVSP  TST     FCAL      CALIBRATE SPEED TRANSDUCER?
00803   1612        BEQ     INV2      NO
00804   1614        TST     FCAL+1    ALREADY STARTED?
00805   1616        BNE     INV1      YES
00806   1618        LDA     .AXIN+1   SW1 DEPRESSED?
00807   1620        BEQ     INV4A     NO
00808   1622        STA     FCAL+1    SET START FLAG
00809   1624        LDD     #0
00810   1626        STD     SPDCAL
00811   1628        BRA     INV4A
00812   1630 INV1   LDA     #$04      COUNTER SELECT CODE
```

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```
00813   1632          LBSR    INPUT       READ COUNTER
00814   1634          CLRA                CLEAR 4 MSB
00815   1636          TST     .AXIN+1     SW1 DEPRESSED?
00816   1638          BEQ     INV1A       NO
00817   1640          CLR     FCAL+1      FINISH CALIBRATION
00818   1642          BRA     INV1B
00819   1644 INV1A    CMPB    #225
00820   1646          BLO     INV5
00821   1648 INV1B    ADDD    SPDCAL      ACCUMULATE COUNT
00822   1650          BPL     INV1C       NO 2'S COMP. COUNTER OVERFLOW
00823   1652          LDB     #ERRSOF
00824   1654          STB     FFLT
00825   1656          LDD     #1          SET MINIMUM VALUE
00826   1658          CLR     FCAL+1
00827   1660 INV1C    STD     SPDCAL
00828   1662          BRA     INV4A
00829   1664 INV2     LDD     SPDCAL
00830   1666          BNE     INV3        FACTOR VALID
00831   1668          LDD     #1754       USE DEFAULT SETTING
00832   1670          STD     SPDCAL
00833   1672 INV3     LDA     SPDC
00834   1674          INCA
00835   1676          CMPA    #45         6 SEC (45X.133S)
00836   1678          BLO     INV5A       NO
00837   1680          LDA     #$04        COUNTER SELECT CODE
00838   1682          LBSR    INPUT
00839   1684          CMPB    #200        COUNTER WITHIN RANGE?
00840   1686          BLO     INV4        YES
00841   1688          LDA     #ERRSHI
00842   1690          STA     FFLT        SET FAULT CODE
00843   1692          CLRB                CLEAR LOWER BYTE
00844   1694 INV4     CLRA                CLEAR UPPER BYTE
00845   1696          STD     SPEED
00846   1698 INV4A    LDA     #$05
00847   1700          LBSR    DEVSEL      RESET HARDWARE COUNTER
00848   1702 INV5     CLRA                RESET LOOP COUNTER
00849   1704 INV5A    STA     SPDC        SAVE PRESENT SPEED COUNTER
00850   1706          RTS
00851   1708          PAGE
00852   1710 **
00853   1712 **     DISPLAY SELECT - SUBROUTINE
00854   1714 **
00855   1716 **     SELECTS APPROPRIATE DISPLAY FOR V.F. & LED INDICATORS
00856   1718 **     DEPENDING UPON CURRENT OPERATING MODE - NORMAL DISPLAY
00857   1720 **     & IF SW1 (REMOTE DISPLAY) DEPRESSED - REQUESTED DISPLAY
00858   1722 **
00859   1724 **     ANNUNCIATORS ARE SET BASED UPON FLAGS
00860   1726 **     OR ASSOCIATED INPUTS
00861   1728 **
00862   1730 **     FLASHING OF DESIGNATED ANNUNCIATORS WHEN ACTIVATED
00863   1732 **
00864   1734 **
00865   1736 **     SPECIAL FUNCTIONS INCLUDE :
00866   1738 **           TEST AND FAULT MODES
00867   1740 **           TRIGGER BY FTST & FFLT
00868   1742 **           TRANSFERRING CONTROL TO DISTST & DISFLT ROUTINES
00869   1744 **
00870   1746 **
```

```
00871   1748          PSCT
00872   1750  *
00873   1752  DISSEL  TST     FTST        CHECK FOR TEST MODE
00874   1754          BNE     DISTST
00875   1756          CLR     FTST+1
00876   1758          TST     FFLT        CHECK FOR FAULT MODE
00877   1760          LBNE    DISFLT
00878   1762          TST     FCAL        CHECK FOR CALIBRATE MODE
00879   1764          LBNE    DISCAL
00880   1766          CLR     FCAL+1
00881   1768          CLR     FLASHL
00882   1770          CLR     FLASHV
00883   1772          LDY     PMODE       SET MODE POINTER
00884   1774          TST     .AXIN
00885   1776          BMI     DIS1        REMOTE DISPLAY PUSHBUTTON (SW1) - DEPRESSED
00886   1778          LDA     DDELAY
00887   1780          BNE     DIS2        HOLD REQUESTED DISPLAY
00888   1782          LDD     DISP1,Y     SELECT NORMAL DISPLAY FORMAT
00889   1784          BRA     DIS3
00890   1786  DIS1    LDA     #38         (38 x .133)-1=5 SEC.
00891   1788  DIS2    DECA
00892   1790          STA     DDELAY
00893   1792          LDD     DISP2,Y     SELECT REQUESTED DISPLAY FORMAT
00894   1794  *
00895   1796  DIS3    STA     DSTAT       SET VFD STATUS
00896   1798          STB     .FPOUT+1    SET FRONT PANEL LED'S MASK
00897   1800          CLR     .FPOUT      RESET ALL LED'S
00898   1802          LDA     #$FF
00899   1804          STA     DSTATM      ENABLE ALL FUNCTIONS
00900   1806  *
00901   1808          LBSR    ACPWR       AC-ON INDICATOR
00902   1810          LBSR    ELOW        WATER INDICATOR
00903   1812          LBSR    CHGLED      CHARGING INDICATOR
00904   1814          LBSR    EQUAL       EQUALIZE INDICATOR
00905   1816          LBSR    WARN        WARNING INDICATOR
00906   1818          LBSR    SOC         SOC INDICATOR
00907   1820          LBSR    FLASH       FLASH INDICATORS
00908   1822  *
00909   1824          LDA     DMILE+1     MILES REMAINING - LSB
00910   1826          LBSR    BCD         CONVERT TO DISPLAYABLE FORM
00911   1828          LDB     #$80
00912   1830          ORB     DNUM        SET MILES INDICATOR
00913   1832          STB     DNUM
00914   1834          RTS
00915   1836          PAGE
00916   1838  *       SPECIAL TEST DISPLAY ROUTINE
00917   1840  *        INHIBITS NORMAL DISPLAY ; USES 3 DIGIT NUMERIC TO
00918   1842  *        DISPLAY BCD VALUE OF ANY SYSTEM VARIABLES.
00919   1844  *        TABLE : TBLTST DEFINES VARIABLES & THEIR DISPLAYED ORDER
00920   1846  *
00921   1848  *        SW1 REMOTE DISPLAY PUSHBUTTON STEPS THROUGH TABLE
00922   1850  *
00923   1852  *        BAR-GRAPH USED TO INDICATE DISPLAYED VARIABLE
00924   1854  *                ( i.e.  3 BARS FOR 3'RD ELEMENT IN TABLE )
00925   1856  *
00926   1858  *        WARNING INDICATOR FLASHES TO INDICATE NON-NORMAL DISPLAY
00927   1860  *
00928   1862  *
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```
00929   1864 DISTST TST     FTST+1     TEST ALREADY RUNNING ?
00930   1866        BEQ     DIST0      NO, INITIALIZE
00931   1868        LDX     TSTPTR     RETAIN LAST POINTER LOCATION
00932   1870        LDB     .AXIN+1    REMOTE PUSHBUTTON DEPRESSED?
00933   1872        BEQ     DIST1      NO
00934   1874        INC     DBAR
00935   1876        LEAX    2,X        ADVANCE POINTER TO NEXT ENTRY
00936   1878        CMPX    #TBLTSE+2  END OF TABLE
00937   1880        BNE     DIST1      NO
00938   1882 DIST0  CLR     DBAR
00939   1884        LDA     #$01
00940   1886        STA     FTST+1     SET RUN FLAG
00941   1888        LDX     #TBLTST
00942   1890 DIST1  STX     TSTPTR     RESET POINTER
00943   1892        LDA     [0,X]      FETCH TABLE VALUE
00944   1894        LBSR    BCD        CONVERT BINARY TO BCD VALUE
00945   1896        LDA     #$87       SET WARNING,BAR,NUMERIC GRID "ON"
00946   1898        STA     DSTAT
00947   1900        STA     DSTATM
00948   1902        LDB     #$80       SET WARNING TO FLASH
00949   1904        STB     FLASHV
00950   1906        LDD     #$0
00951   1908        STD     .FPO.T     BLANK LED'S
00952   1910        LBRA    FLASH      FLASH DISPLAYS & RETURN
00953   1912        PAGE
00954   1914 *
00955   1916 *      SPECIAL FAULT DISPLAY - ROUTINE
00956   1918 *
00957   1920 *      DISPLAYS NUMERIC FAULT CODE FROM FFLT
00958   1922 *      4 MSB PRIMARY (P) & LSB SECONDARY CODE (S)
00959   1924 *            IN  P - S  FORMAT
00960   1926 *      WARNING AND FAULT INDICATORS FLASH
00961   1928 *
00962   1930 DTSFLT LDA     #$8B       WARNING, FAULT, NUMERIC, GRID ACTIVATED
00963   1932        STA     DSTAT
00964   1934        STA     DSTATM
00965   1936        LDB     #$8B       WARNING FAULT FLASH
00966   1938        STB     FLASHV
00967   1940        LDB     FFLT       FAULT CODE & FLAG
00968   1942        TFR     B,A
00969   1944        ANDA    #$0F
00970   1946        STA     DNUM+2     SAVE SECONDARY CODE
00971   1948        LDA     #16
00972   1950        MUL                SEPARATE PRIMARY & SECONDARY CODES
00973   1952        STA     DNUM       SAVE PRIMARY CODE
00974   1954        LDB     #$0A       NEGATIVE SIGN CODE
00975   1956        STB     DNUM+1     INSERT BETWEEN CODES
00976   1958        LDD     #$0808
00977   1960        STD     .FPOUT     ACTIVATE FRONT PANEL FAULT INDICATION
00978   1962        STA     FLASHL     FLASH LED FAULT
00979   1964        LBSR    FLASH      FLASH DISPLAYS
00980   1966        LDA     DFLTC
00981   1968        INCA               ADVANCE FAULT DELAY COUNT
00982   1970        CMPA    #22        DISPLAY 3 SEC. (22 X .133) YET?
00983   1972        BLS     DISFL1     NO
00984   1974        CLR     FFLT       RESET FAULT CODE
00985   1976        CLRA               RESET DELAY COUNT
00986   1978 DISFL1 STA     DFLTC      SAVE DELAY COUNT
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```
00987   1980          RTS
00988   1982          SPC     3
00989   1984 *
00990   1986 *     SPECIAL CALIBRATE DISPLAY
00991   1988 *       DISPLAYS M.S. BYTE OF CALIBRATION FACTOR
00992   1990 *       FLASHING FACTOR INDICATES CALIBRATION IN PROGRESS
00993   1992 *
00994   1994 DISCAL  LDA     #$83       SELECT WARNING & NUMERIC
00995   1996         STA     DSTAT
00996   1998         STA     DSTATM
00997   2000         LDB     #$80       FLASH WARNING
00998   2002         TST     FCAL+1     CALIBRATION IN PROGRESS?
00999   2004         BEQ     DISC1      NO
01000   2006         LDB     #$02       FLASH NUMERIC
01001   2008 DISC1   STB     FLASHV
01002   2010         LDD     #$0
01003   2012         STD     .FPOUT     BLANK LED DISPLAY
01004   2014         LDA     SPDCAL     DISPLAY M.S. BYTE OF FACTOR
01005   2016         LBSR    BCD
01006   2018         LBRA    FLASH      FLASH DISPLAY & RETURN
01007   2020         PAGE
01008   2022 **
01009   2024 **    CONFIGURE BIT PATTERN FOR V.F. DISPLAY
01010   2026 **
01011   2028 **      FORMS PROPER BIT SEQUENCE FOR LATER USE BY
01012   2030 **      VFDIS SUBROUTINE
01013   2032 **
01014   2034 **        INPUTS: DSTAT , DSTATM , DBAR , DNUM(3) , FDNEW
01015   2036 **        USES: X , Y , A , B , S ; IDISP , TBLNUM , TBLBAR
01016   2038 **        OUTPUTS: VFDATA - VFDATA+5
01017   2040 **        RETURNS
01018   2042 **
01019   2044 CDISP   LBSR    IDISP
01020   2046         LDA     DSTAT
01021   2048         ANDA    DSTATM     MASK DISPLAY STATUS
01022   2050         PSHS    A
01023   2052         TFR     A,B
01024   2054         ANDB    #$F0       RETAIN ANNUNCIATOR STATUS ONLY
01025   2056         ORB     5,Y
01026   2058         STB     5,Y        SAVE AT VFDAT6
01027   2060 *
01028   2062         BITA    #$01       TEST "GRID" BIT
01029   2064         BEQ     CDISP1     "OFF"
01030   2066         LDB     #$04
01031   2068         ORB     0,Y
01032   2070         STB     0,Y
01033   2072 *
01034   2074 CDISP1  BITA    #$08       TEST "FAULT" BIT
01035   2076         BEQ     CDISP2     "OFF"
01036   2078         LDB     #$08
01037   2080         ORB     3,Y
01038   2082         STB     3,Y        ACTIVATE FAULT INDICATOR
01039   2084 *
01040   2086 CDISP2  BITA    #$04       TEST BAR-GRAPH REQUEST BIT
01041   2088         BEQ     CDISP3     DO NOT DISPLAY BAR-GRAPH
01042   2090         LDX     #TBLBAR    SET POINT TO 1'ST TABLE ENTRY
01043   2092         LDB     DBAR       BAR-GRAPH DATA
01044   2094         CMPB    #(TBLBAE-TBLBAR)/2 CHECK FOR MAX. TABLE SIZE
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01045  2096          BLS     *+4         OK
01046  2098          LDB     #(TBLBAE-TBLBAR)/2 SET MAX. SIZE
01047  2100          LSLB                DOUBLE BYTE TABLE X 2
01048  2102          ABX                 OFFSET POINTER
01049  2104          LDA     0,X
01050  2106          LDB     1,X
01051  2108          ORA     3,Y
01052  2110          STA     3,Y         SAVE AT VFDATA+3
01053  2112          STB     4,Y         SAVE AT VFDATA+4
01054  2114 *
01055  2116 CDISP3   PULS    A
01056  2118          BITA    #$02
01057  2120          BEQ     CDISP4
01058  2122          LDX     #TBLNUM     CONVERT BCD TO SEVEN SEGMENTS
01059  2124          LDB     DNUM        100'S
01060  2126          BSR     TBL
01061  2128          LDA     #8
01062  2130          MUL                 SHIFT LEFT FOUR TIMES
01063  2132          ORA     0,Y
01064  2134          STA     0,Y
01065  2136          STB     1,Y
01066  2138 *
01067  2140          LDB     DNUM+1      10'S
01068  2142          BSR     TBL
01069  2144          LDA     #16
01070  2146          MUL
01071  2148          ORA     1,Y
01072  2150          STA     1,Y
01073  2152          STB     2,Y
01074  2154 *
01075  2156          LDB     DNUM+2      1'S
01076  2158          BSR     TBL
01077  2160          LDA     #32
01078  2162          MUL
01079  2164          ORA     2,Y
01080  2166          STA     2,Y
01081  2168          ORB     3,Y
01082  2170          PSHS    B
01083  2172          LDA     DNUM
01084  2174          ANDA    #$C0        ISOLATE MILES & FAULT ANNUNCIATORS
01085  2176          LSRA
01086  2178          LSRA
01087  2180          LSRA
01088  2182          ORA     0,S+
01089  2184          STA     3,Y
01090  2186 CDISP4   RTS
01091  2188 *
01092  2190 *      TABLE LOOK-UP SUBROUTINE FOR 16 ENTRY TABLE
01093  2192 *
01094  2194 *        INPUT   'X' REG POINTING TO 1'ST TABLE ADDRESS
01095  2196 *                'B' REG ARGUMENT
01096  2198 *        OUTPUT: 'B' REG - VALUE FROM TABLE
01097  2200 *
01098  2202 TBL      ANDB    #$0F
01099  2204          LDB     B,X
01100  2206          RTS
01101  2208          SPC     3
01102  2210          PAGE
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01103    2212 **
01104    2214 **        VACUUM FLUORESCENT DISPLAY SUBROUTINE
01105    2216 **
01106    2218 **         TRANSMITS TO DISPLAY SERIAL BIT PATTERN PREVIOUSLY
01107    2220 **         STORED AT     VFDATA-VFDATA+5
01108    2222 **
01109    2224 **         SEQUENCE IS REPEATED THREE CONSECUTIVE TIMES
01110    2226 **
01111    2228 **         FDISP FLAG DETERMINES WHETHER DISPLAY IS ACTIVE OR BLANKI
01112    2230 **
01113    2232 VFDISP LDA     DSTAT     CHECK FOR GRID ACTIVE COMMAND
01114    2234        LSRA
01115    2236        LBCC    BLANK     NO,BLANK DISPLAY & RETURN
01116    2238        LDA     #$03      TRANSMIT 3 TIMES
01117    2240        STA     LOOPC     PRESET LOOP COUNTER
01118    2242 VFDIS1 LDX     #VFDATA+5 SET POINTER FOR FIRST BYTE TO BE TRANSMITT
01119    2244        LDB     PIAXAD    SET CLOCK'="1" (PA5)
01120    2246        ORB     #$20
01121    2248 VFDIS2 LDA     #$08
01122    2250        STA     BITC      PRESET BIT COUNTER
01123    2252        LDA     0,X
01124    2254 VFDIS3 LSRA              USE CARRY TO TEST BITS
01125    2256        ORB     #$10      SEGMENT OFF DATA'="1" (PA4)
01126    2258        BCC     *+4
01127    2260        ANDB    #$EF      SEGMENT ON DATA'="0" (PA4)
01128    2262        STB     PIA1AD
01129    2264        NOP               WAIT 9uS BEFORE CLOCKING
01130    2266        ANDB    #$DF
01131    2268        STB     PIA1AD    SET CLOCK'="0" (PA5)
01132    2270        ORB     #$20
01133    2272        STB     PIA1AD    SET CLOCK'="1"
01134    2274        DEC     BITC
01135    2276        BNE     VFDIS3    FULL BYTE NOT TRANSMITTED
01136    2278        LEAX    -1,X
01137    2280        CMPX    #VFDATA-1
01138    2282        BNE     VFDIS2    ALL BYTES NOT TRANSMITTED
01139    2284        ORB     #$40      LATCH DATA INTO DRIVERS
01140    2286        STAB    PIA1AD    SET STROBE="1"
01141    2288        NOP
01142    2290        ANDB    #$BF      WAIT 9uS
01143    2292        STB     PIA1AD    SET STROBE="0"
01144    2294        STB     PIAXAD    DUPLICATE IN RAM
01145    2296        DEC     LOOPC
01146    2298        BNE     VFDIS1    REPEAT TRANSMIT SEQUENCE
01147    2300        RTS
01148    2302        SPC     3
01149    2304 *
01150    2306 *      BLANK VACUUM FLUORESCENT DISPLAY
01151    2308 *
01152    2310 *       BLANKS DISPLAY BY TURNING OFF FILAMENT
01153    2312 *         "LOW POWER MODE"
01154    2314 *
01155    2316 BLANK  LDA     #$7F      FORCE STROBE "HIGH" (PA6)
01156    2318        STA     PIA1AD
01157    2320        STA     PIAXAD    DUPLICATE IN RAM
01158    2322        RTS
01159    2324        PAGE
01160    2326 **
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01161   2328 **     SAFETY - SUBROUTINE
01162   2330 **      RUNS SPECIFIC FAULT DIAGNOSTICS DURING
01163   2332 **      PROGRAM EXECUTION AND CAN TRIGGER SPECIAL
01164   2334 **      FAULT DISPLAY OR EMERGENCY SHUTDOWN (POWER STAGE DISABLED)
01165   2336 **
01166   2338 SAFETY CLR     DISAF     RESET DI  BLE FLAG
01167   2340         LDY     #(TBLTEE-TBLTEM+1)/6 SET COUNTER
01168   2342         LDX     #TBLTEM   POINT TO 1'ST TABLE ENTRY
01169   2344         LDU     #GLOBAL   SET GLOBAL POINTER
01170   2346 SAFE1   LDA     0,X       READ OFFSET
01171   2348         LDD     A,U       READ VALUE
01172   2350         CMPD    1,X       ABOVE LOWER LIMIT
01173   2352         BGT     SAFE3     NO
01174   2354         CMPD    3,X       ABOVE UPPER LIMIT
01175   2356         BGE     SAFE2     NO
01176   2358         LDB     5,X
01177   2360         STB     DISAF     SET DISABLE FLAG
01178   2362 SAFE2   LDB     5,X
01179   2364         STB     FFLT      SET APPROPRIATE ERROR CODE
01180   2366 SAFE3   LEAX    6,X
01181   2368         LEAY    -1,Y
01182   2370         BNE     SAFE1
01183   2372 *
01184   2374         LDA     FFIN
01185   2376         ANDA    #$07
01186   2378         CMPA    #06       TEST FOR VALID INPUT CODES
01187   2380         BLT     SAFE4     O.K.
01188   2382         LDB     #ERRFPI
01189   2384         STB     FFLT      SET APPROPRIATE ERROR CODE
01190   2386 SAFE4   RTS
01191   2388         SPC     6
01192   2390 **
01193   2392 **     SYSTEM SHUTDOWN SUBROUTINE
01194   2394 **      SETS WAKE-UP MOD
01195   2396 **      AND REMOVES LOGIC POWER
01196   2398 **
01197   2400 SHUTD   ORCC    #$50      SET FIRQ & IRQ MASK
01198   2402         LDA     #$7F
01199   2404         STA     PIA1AD    BLANK VFD
01200   2406         STA     PIAXAD    DUPLICATE IN RAM
01201   2408         LDA     #$FF
01202   2410         STA     RTCLRE    RESET ALL LATCHES
01203   2412         STA     RTCCRE    RESET ALL COUNTERS
01204   2414         LDD     WAKEF     BCD CODED WAKE-UP TIME
01205   2416         BNE     SHUTD1
01206   2418         LDD     #$0100    1 DAY - 0 HR DEFAULT SETTING
01207   2420 SHUTD1  ADDD    #$0100    ADJUST DAYS FOR INITIALIZATION POINT
01208   2422         STA     RTCLDM    DAYS (0-30)
01209   2424         STB     RTCLH     HOURS(0-23)
01210   2426         LDA     #$01
01211   2428         STA     RTCLDW    INITIALIZE LATCHES TO AGREE WITH COUNTERS
01212   2430         STA     RTCLMO
01213   2432         STA     RTCSBY    ENABLE STANDBY INTERRUPT
01214   2434         STA     RTCICR    ENABLE COMPARATOR FLAG
01215   2436         LDX     #$0
01216   2438         STX     WARMF     RESET RUNNING FLAG
01217   2440         CLR     CCOUT
01218   2442         STX     FPOUT     BLANK LED'S
```

```
01219   2444          CLR     .AXOUT    CLEAR HOLD BIT
01220   2446          LBSR    DOUT      KILL POWER
01221   2448 SHUTD2   BRA     SHUTD2    WAIT TO DIE
01222   2450          SPC     3
01223   2452 **
01224   2454 **     ADJUST TIME FOR SHUTDOWN INTERVAL
01225   2456 **
01226   2458 TIMEA    LDX     #RTCCM
01227   2460 TIMA1    LDY     0,X       READ MIN. AND HOUR COUNTER
01228   2462          LDA     3,X       READ DAY OF MONTH COUNTER
01229   2464          TST     RTCSR     COUNTER ROLLOVER?
01230   2466          BNE     TIMA1     YES
01231   2468          PSHS    A,Y
01232   2470          LDB     #02
01233   2472 TIMA2    LDA     B,S
01234   2474          LBSR    BINARY    CONVERT BCD TO BINARY
01235   2476          STA     B,S
01236   2478          DECB
01237   2480          BPL     TIMA2
01238   2482          LDA     0,S+
01239   2484          SUBA    #1        CORRECT FOR CLOCK INITIALIZATION
01240   2486          LDB     #24       CONVERT TO DAYS
01241   2488          MUL
01242   2490          ADDB    1,S       INCLUDE HOUR COUNTER VALUE
01243   2492          ADCA    #0
01244   2494          TFR     D,Y
01245   2496          LDB     #60
01246   2498          PSHS    B
01247   2500          TFR     Y,D
01248   2502          LBSR    QMUL      CONVERT TO HOURS
01249   2504          ADDB    1,S       INCLUDE COUNTER VALUE
01250   2506          ADCA    #0
01251   2508          LSRA
01252   2510          RORB              WEIGHT TIME FOR 2MIN/COUNT
01253   2512          BCC     TIMA3     ROUND ANSWER
01254   2514          ADDD    #$01
01255   2516 TIMA3    LEAS    3,S       CLEAN STACK & FALL INTO TIME
01256   2518          SPC     3
01257   2520 **
01258   2522 **     SUBROUTINE TO ADVANCE TIME COUNTERS
01259   2524 **      BASED UPON VALUE STORED IN D' REG UPON ENTRY
01260   2526 **
01261   2528 TIME     TFR     D,Y
01262   2530          LDX     #TBLTIM   1ST TIME LOCATION
01263   2532 TIM1     ADDD    [0,X]     ADVANCE COUNT
01264   2534          BCC     TIM2
01265   2536          LDD     #$FFFF    SET MAX VALUE
01266   2538 TIM2     STD     [0,X]     SAVE NEW COUNT
01267   2540          LEAX    2,X       NEXT TIME LOCATION
01268   2542          TFR     Y,D       RE-COPY ORGINAL VALUE
01269   2544          CMPX    #TBLTIE   END OF TABLE
01270   2546          BLS     TIM1      NO
01271   2548          RTS
01272   2550          SPC     6
01273   2552 **
01274   2554 **     LINEARIZING TABLE LOOK-UP
01275   2556 **
01276   2558 **     V=V0+(V0-V1)(A-A0)/256
```

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```
01277   2560 **
01278   2562 **         "X" -  REG = POINTER TO 1ST TABLE LOCATION
01279   2564 **         "A,B"    12BIT POSITIVE VALUE
01280   2566 **
01281   2568 **       TABLE VALUES: 8BIT UNSIGNED NUMBERS
01282   2570 **     RESULT: V<256 IN "A,B" - REG
01283   2572 **
01284   2574 LTBL    TSTA              NUMBER POSITIVE?
01285   2576         BPL     LTBL1     YES; LINEARIZE FROM TABLE
01286   2578         CLRB
01287   2580         BRA     LTBL2     DEFAULT TO LOWEST TABLE ENTRY
01288   2582 LTBL1   EXG     A,B
01289   2584         ABX               ADJUST POINTER BY CORRECT OFFSET
01290   2586         LDB     0,X       READ LOWER VALUE (V0)
01291   2588         SUBB    1,X       -(V1)
01292   2590         BHS     *+3
01293   2592         NEGB              FORM ABSOLUTE
01294   2594         MUL               (V0-V1)(A-A1)
01295   2596         TSTB              CHECK 8LSB
01296   2598         BPL     *+3
01297   2600         INCA              ROUND 8 MSB
01298   2602         LDB     0,X       DIFFERENCE NEGATIVE
01299   2604         SUBB    1,X
01300   2606         BLS     *+3       POSITIVE SLOPE
01301   2608         NEGA              NO CORRECT FOR UNSIGNED MULTIPLY
01302   2610         TFR     A,B
01303   2612 LTBL2   ADDB    0,X
01304   2614         CLRA
01305   2616         RTS
01306   2618         PAGE
01307   2620 **
01308   2622 **    DIGITAL INPUTS
01309   2624 **
01310   2626 **      FRONT PANEL SWITCHES : FPIN STORAGE LOCATION
01311   2628 **                           : FPIN+1  FLAG BIT CHANGES
01312   2630 **           SELECT CODE 07
01313   2632 **      SW3      B0-B2  0-TEST,1-15 AMP;2-20 AMP;3-30 AMP;4-AUX CHA
01314   2634 **                      5-CALIBRATE,6-UNUSED;7-UNUSED
01315   2636 **      AC-ON    B3   "0" AC-LINE ACTIVE
01316   2638 **      EVC-ON   B6   "0" EV CONTROLLER ACTIVE
01317   2640 **      SW2      B7   "1" DEFER EQUALIZE CYCLE-DEBOUNCED
01318   2642 **
01319   2644 **       DIP & MISC. INPUTS : SYIN      STORAGE LOCATION
01320   2646 **           SELECT CODE 08
01321   2648 **
01322   2650 **       BATTERY TYPE B0-B1  0-GOULD ; 1-UNUSED ; 2-UNUSED ; 3-UNU
01323   2652 **                          (DIP SWITCH #1&2)
01324   2654 **       CALIBRATE MODE       B2      "1" ACTIVE (DIP SWITCH #3)
01325   2656 **
01326   2658 **       TEST MODE            B3      "1" ACTIVE (DIP SWITCH #4)
01327   2660 **
01328   2662 **       POWER STAGE FAULT    B6      "0"  FAULT
01329   2664 **
01330   2666 **       ELECTROLYTE LOW      B7      "1"  LOW
01331   2668 **
01332   2670 **    REMOTE DISPLAY & AUX. INPUTS : .AXIN
01333   2672 **                                 : .AXIN+1  FLAGS A "1"-"0" CHAN
01334   2674 **
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```
01335   2676 **        SW1                     B7      "0"  DEPRESSED -FILTERED
01336   2678 **
01337   2680 DINPUT LDA     #07       FRONT PANEL SELECT CODE
01338   2682        BSR     INPUT     READ CURRENT VALUE
01339   2684        ANDB    #$CF      MASK OFF USED INPUTS
01340   2686        TFR     B,A
01341   2688        EORB    FPIN    FORM CHANGE INDICATION
01342   2690        STD     FPIN    SAVE NEW VALUE  & CHANGE INFORMATION
01343   2692 *
01344   2694 DIN1   LDA     #08       SYSTEM INPUT SELECT CODE
01345   2696        BSR     INPUT     READ VALUE
01346   2698        ANDB    #$CF      SELECT USED INPUTS
01347   2700        STB     SYIN    SAVE VALUE & CHANGES
01348   2702 *
01349   2704 DIN2   CLRB
01350   2706        LDA     PIA1AD    AUXILIARY INPUTS***CAUTION***MAY CLEAR FIRQ
01351   2708        COMA              REVERSE LOGIC SENSE; "1"=DEPRESSED
01352   2710        ANDA    #$80      SELECT USED INPUTS - B7
01353   2712        BPL     DINP      NOT DEPRESSED
01354   2714        CMPA    .AXIN     FLAG - CHANGES
01355   2716        BEQ     DINP
01356   2718        LDB     #$80      SW1 JUST DEPRESSED
01357   2720 DINP   STD     .AXIN     SAVE VALUE & CHANGE
01358   2722        RTS
01359   2724        PAGE
01360   2726 **
01361   2728 **
01362   2730 **         DIGITAL OUTPUTS
01363   2732 **
01364   2734 **           POWER STAGE CONTROL : CCOUT ( D SELECT CODE)
01365   2736 **           DATA      B0-B6     BINARY
01366   2738 **           ENABLE    B7        "1" ACTIVE
01367   2740 **
01368   2742 **
01369   2744 **         FRONT PANEL INDICATORS : .FPOUT , .FPOUT +1 (A SELECT CO
01370   2746 **               CHARGING     PB0     "1" ON
01371   2748 **               EQUALIZE     PB1     "1" ON
01372   2750 **               WATER BAT.   PB2     "1" ON
01373   2752 **               FAULT        PB3     "1" ON
01374   2754 **                            PB4-PB5  UNUSED
01375   2756 **
01376   2758 **             MISC. OUTPUTS : .AXOUT (B SELECT CODE)
01377   2760 **               L.P.S. FAULT  PB0    "1" ON     BOARD LED'S
01378   2762 **               uC FAULT      PB1    "1" ON     BOARD LED'S
01379   2764 **               I/O FAULT     PB2    "1" ON     BOARD LED'S
01380   2766 **                             PB3-PB4  UNUSED
01381   2768 **               L.P.S. HOLD   PB7    "1" ACTIVE
01382   2770 **
01383   2772 **
01384   2774 DOUT   LDA     #$0D      DEVICE SELECT CODE
01385   2776        LDB     CCOUT
01386   2778        BSR     OUTPUT
01387   2780 *
01388   2782 DOUT1  LDA     #$0A      DEVICE SELECT CODE
01389   2784        LDB      FPOUT    FRONT PANEL DATA
01390   2786        ANDB    .FPOUT+1  ENABLE MASK
01391   2788        BSR     OUTPUT
01392   2790 *
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01393   2792 DOUT2  LDA     #$0B      DEVICE SELECT CODE
01394   2794        LDB     .AXOUT    AUX. OUTPUT
01395   2796        BSR     OUTPUT
01396   2798        RTS
01397   2800        PAGE
01398   2802 *
01399   2804 *         PIA OUTPUT
01400   2806 *              ENTRY - "A" DEVICE CODE ; "B" DATA TO BE OUTPUTED
01401   2808 *                 NON-INTERRUPTIBLE  ( 64 CYCLES )
01402   2810 *                 0,X  PIA1AD       2,X  PIA1BD
01403   2812 *                 1,X  PIA1AC       3,X  PIA1BC
01404   2814 *
01405   2816 OUTPUT LDX     #PIA1AD   SET PIA REFERENCE PTR.
01406   2818        PSHS    A         TEMP. SAVE DEVICE CODE
01407   2820        LDA     #$F0
01408   2822        ANDA    PIAXAD    RETAIN PB7-PB4
01409   2824        ORA     0,S+      MERGE NEW DEVICE CODE
01410   2826        STA     0,X       OUTPUT DEVICE CODE
01411   2828        LDA     #PIABDR
01412   2830        STA     3,X       SELECT "B" DATA DIRECTION REG.
01413   2832        LDA     #$FF
01414   2834        STA     2,X       CONFIGURE AS OUTPUTS
01415   2836        LDA     #PIABPR
01416   2838        STA     3,X       SELECT "B" PERIPHERAL REG.
01417   2840        STB     2,X       OUTPUT DATA
01418   2842        LDA     #DSON
01419   2844        STA     1,X       LATCH DATA OUTPUTED
01420   2846        LDA     #DSOFF
01421   2848        STA     1,X       DEVICE DESELECTED
01422   2850        RTS
01423   2852        SPC     3
01424   2854 *
01425   2856 *         PIA INPUT "B" SIDE ( NON INTERRUPTIBLE ) ( 64 CYCLES )
01426   2858 *          ENTER : A-REG DEVICE CODE  ( NON-USED BITS B7-B4 MUST BE
01427   2860 *          RETURN : B-REG DATA READ
01428   2862 *
01429   2864 *                   PIA1AD   0,X
01430   2866 *                   PIA1AC   1,X
01431   2868 *                   PIA1BD   2,X
01432   2870 *                   PIA1BC   3,X
01433   2872 *
01434   2874 INPUT  LDX     #PIA1AD   SET PIA REFERENCE PTR.
01435   2876        PSHS    A         TEMP SAVE DEVICE CODE
01436   2878        LDA     #$F0
01437   2880        ANDA    PIAXAD    RETAIN PA7 PA4 STATUS
01438   2882        ORA     0,S+      MERGE NEW DEVICE SELECT CODE
01439   2884        STA     0,X       OUTPUT DEVICE SELECT CODE
01440   2886        LDA     #PIABDR
01441   2888        STA     3,X       SELECT "B" DATA DIRECTION REG.
01442   2890        CLR     2,X       CONFIGURE "B" AS INPUTS
01443   2892        LDA     #PIABPR
01444   2894        STA     3,X       SELECT "B" PERIPHERAL REG.
01445   2896        LDA     #DSON
01446   2898        STA     1,X       DEVICE SELECT ACTIVE
01447   2900        LDA     #DSOFF
01448   2902        LDB     2,X       READ DATA
01449   2904        STA     1,X       DEVICE SELECT "DISABLED"
01450   2906        RTS
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01451  2908          SPC   3
01452  2910 *
01453  2912 *          WATCH-DOG RESET - SETS "A" REG. WITH DUMMY SELECT CODE
01454  2914 *           FALLS INTO DEVSEL TO TOGGLE DEVICE SELECT LINE
01455  2916 *
01456  2918 WDOG     LDA   #$0F      SELECT UNUSED DEVICE CODE
01457  2920          SPC   3
01458  2922 *
01459  2924 *          PIA-SELECT CODE OUTPUT (DEVICE SELECT)  ( 43 CYCLES )
01460  2926 *           ENTRY : REG "A" DEVICE CODE   "B" REG UNALTERED
01461  2928 *           NON-INTERRUPTIBLE
01462  2930 *
01463  2932 DEVSEL   PSHS  A           SAVE DEVICE CODE
01464  2934          LDA   #$F0
01465  2936          ANDA  PIAXAD      RETAIN PA7-PA4 STATUS
01466  2938          ORA   0,S+        MERGE DEVICE SELECT CODE
01467  2940          STA   PIA1AD      OUTPUT DEVICE SELECT CODE
01468  2942          LDA   #DSON
01469  2944          STA   PIA1AC      DEVICE SELECT "ACTIVE"
01470  2946          LDA   #DSOFF
01471  2948          STA   PIA1AC
01472  2950          RTS
01473  2952          SPC   3
01474  2954          PAGE
01475  2956 *
01476  2958 *       ELECTROLYTE LEVEL SENSING - ROUTINE
01477  2960 *
01478  2962 *        FILTERS LEVEL SENSING INPUT ( .5 HR. )
01479  2964 *        SETS OR RESETS APPROPRIATE DISPLAY INDICATORS ACCORDINGLY
01480  2966 *        ( LED & VFD )
01481  2968 *         INPUT: SYIN
01482  2970 *         USES: EDELAY(2) X,A,B, REG.
01483  2972 *         OUTPUTS: DSTAT , .FPOUT
01484  2974 *
01485  2976 FILTE1  EQU   6767        FILTER CONSTANT (6767XX  133 SEC)=15 MIN
01486  2978 *
01487  2980 ELOW     LDX   EDELAY
01488  2982          BNE   *+5         VALID DELAY COUNT
01489  2984          LDX   #FILTE1-1 USE DEFAULT SETTING
01490  2986          CMPX  #FILTE1   15 MIN(TIME CONSTANT)
01491  2988          BLT   ELOW1
01492  2990          LDA   #$20        SET WATER INDICATOR "ON" - VFD
01493  2992          ORA   DSTAT
01494  2994          LDB   #$04        SET WATER INDICATOR "ON" - LED
01495  2996          ORB   .FPOUT
01496  2998          BRA   ELOW2
01497  3000 ELOW1    LDA   #$DF        RESET VFD INDICATOR
01498  3002          ANDA  DSTAT
01499  3004          LDB   #$FB        RESET LED INDICATOR
01500  3006          ANDB  .FPOUT
01501  3008 ELOW2    STA   DSTAT       SAVE VFD STATUS
01502  3010          STB   .FPOUT      SAVE LED STATUS
01503  3012          LEAX  1,X         ADVANCE DELAY 1 COUNT
01504  3014          LDA   SYIN
01505  3016          BMI   *+4         ELECTROLYTE LOW INDICATION
01506  3018          LEAX  -2,X        DECREMENT DELAY 1 COUNT
01507  3020          CMPX  #$01        TEST MIN. COUNT
01508  3022          BLT   ELOW3       YES
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01509  3024          CMPX   #FILTE1*2 TEST MAX. COUNT
01510  3026          BGT    ELOW3     YES
01511  3028          STX    EDELAY    SAVE NEW COUNT
01512  3030 ELOW3    RTS
01513  3032          SPC    3
01514  3034 *
01515  3036 *       EQUALIZE STATUS INDICATORS
01516  3038 *
01517  3040 *       SETS OR RESETS VF AND LED INDICATORS
01518  3042 *       DEPENDING UPON STATUS OF FEQU+1 ; 0 - RESETS ,ELSE- SETS
01519  3044 *        INPUTS : FEQU+1, DSTAT, .FPOUT
01520  3046 *        USES : A, B, REG.
01521  3048 *        OUTPUTS : DSTAT, .FPOUT
01522  3050 *
01523  3052 EQUAL    TST    FEQU+1    TEST EQUALIZE REQUEST FLAG
01524  3054          BEQ    EQUAL1    INDICATORS "OFF" & RETURN
01525  3056          LDA    #$10      "EQUALIZE" ON - VFD
01526  3058          ORA    DSTAT
01527  3060          LDB    #$02      "EQUALIZE" ON - LED
01528  3062          ORB    .FPOUT
01529  3064          BRA    EQUAL3
01530  3066 EQUAL1   LDA    #$EF      "EQUALIZE" OFF - VFD
01531  3068          ANDA   DSTAT
01532  3070          LDB    #$FD      "EQUALIZE" OFF - LED
01533  3072          ANDB   .FPOUT
01534  3074 EQUAL3   STA    DSTAT     SAVE VFD STATUS
01535  3076          STB    .FPOUT    SAVE LED STATUS
01536  3078          RTS
01537  3080          SPC    3
01538  3082 *
01539  3084 *       AC POWER STATUS INDICATOR
01540  3086 *          FLAG: FPIN (B3)
01541  3088 *             "0": AC-ON
01542  3090 *             "1": OFF
01543  3092 *
01544  3094 ACPWR    LDA    FPIN
01545  3096          BITA   #$08
01546  3098          BNE    ACPWR1    AC POWER OFF
01547  3100          LDA    #$40      "AC-ON" ON -VFD
01548  3102          ORA    DSTAT
01549  3104          BRA    ACPWR2
01550  3106 ACPWR1   LDA    #$BF
01551  3108          ANDA   DSTAT
01552  3110 ACPWR2   STA    DSTAT
01553  3112          RTS
01554  3114          SPC    3
01555  3116 *
01556  3118 *       CHARGING STATUS INDICATOR
01557  3120 *         FLAG : FCHG
01558  3122 *           =0 : LED OFF
01559  3124 *           >0 : LED ON
01560  3126 *           <0 : LED FLASHING
01561  3128 *
01562  3130 CHGLED   TST    FCHGL
01563  3132          BEQ    CHGL1
01564  3134          LDA    .FPOUT
01565  3136          ORA    #$01
01566  3138          STA    .FPOUT    SET LED ON
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01567  3140          TST     FCHGL     POSITIVE ?
01568  3142          BPL     CHGL2     YES
01569  3144          LDA     FLASHL
01570  3146          ORA     #$01
01571  3148          STA     FLASHL    SET LED TO FLASH
01572  3150          BRA     CHGL2
01573  3152 CHGL1    LDA     .FPOUT
01574  3154          ANDA    #$FE
01575  3156          STA     .FPOUT    TURN LED OFF
01576  3158 CHGL2    RTS
01577  3160          SPC     3
01578  3162 *
01579  3164 *       WARNING INDICATOR
01580  3166 *         FLAG : FWARN
01581  3168 *           =0 : OFF
01582  3170 *           >0 : ON
01583  3172 *           <0 : FLASHING
01584  3174 *
01585  3176 WARN     TST     FWARN
01586  3178          BEQ     WARN1
01587  3180          LDA     DSTAT
01588  3182          ORA     #$80
01589  3184          STA     DSTAT     SET WARNING ON
01590  3186          TST     FWARN
01591  3188          BPL     WARN2
01592  3190          LDA     FLASHV
01593  3192          ORA     #$80
01594  3194          STA     FLASHV    SET FLASH ON
01595  3196          BRA     WARN2
01596  3198 WARN1    LDA     DSTAT
01597  3200          ANDA    #$7F
01598  3202          STA     DSTAT     TURN WARNING OFF
01599  3204 WARN2    RTS
01600  3206          SPC     3
01601  3208 *
01602  3210 *       SOC - SUBROUTINE
01603  3212 *             DISPLAYS BARGRAPH 0-100%
01604  3214 *             FLASHES IF DSOC =0 TO 20%
01605  3216 *             DSOC 16 BIT FORTRAN INTERGER
01606  3218 *             DBAR 8 BIT DISPLAY
01607  3220 *
01608  3222 SOC      LDD     DSOC      DISPLAY STATE OF CHARGE
01609  3224          BPL     *+3       DON'T DISPLAY NEGATIVE VALUE
01610  3226          CLRB
01611  3228          STB     DBAR      ON BAR-GRAPH - 8LSB
01612  3230          CMPB    #2        0,10%,OR 20%
01613  3232          BHI     SOC1      NO
01614  3234          LDA     FLASHV
01615  3236          ORA     #$04      SET FLASH CODE
01616  3238          STA     FLASHV
01617  3240 SOC1     RTS
01618  3242          SPC     3
01619  3244 *
01620  3246 *       FLASH - SUBROUTINE
01621  3248 *
01622  3250 *         FLASHES APPROPRIATE INDICATOR ON VFD OR LED
01623  3252 *         BASED UPON FFLASH+1, FFLASH+2, "1" FLASHES
01624  3254 *         FLASH RATE DEPENDENT ON SETTING AND RESULTING OF FFL
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01625   3256 *
01626   3258 *        INPUT : FFLASH, FFLASH+1, FFLASH+2, DSTATM, .FPOUT+1
01627   3260 *        USES : A,B REG.
01628   3262 *        OUTPUT : DSTATM, .FPOUT+1
01629   3264 *
01630   3266 FLASH  TST     FFLASH    FLASH REQUEST?
01631   3268       BPL     FLASH1    NO
01632   3270       LDA     DSTATM
01633   3272       LDB     .FPOUT+1
01634   3274       EORA    FLASHV    VFD - BLANK NORMALLY ON ELEMENTS
01635   3276       EORB    FLASHL    LED - BLANK NORMALLY ON INDICATORS
01636   3278       STA     DSTATM
01637   3280       STB     .FPOUT+1
01638   3282 FLASH1 RTS
01639   3284       PAGE
01640   3286 *
01641   3288 *     SUBROUTINE . QUICK MULTIPLIER ( RE-ENTRANT ) 16x7 BIT
01642   3290 *         (A,B) * STACK(S)              115 CYCLES - POS.
01643   3292 *         A,B 16 BIT SIGNED NUMBER  170 CYCLES - NEG.
01644   3294 *         MULTIPLIER PRESAVED ON STACK(S) POSITIVE NUMBER <= 128
01645   3296 *         RESULT : STACK,A,B 24 BIT SIGNED NUMBER
01646   3298 *
01647   3300 QMUL   LEAS  -4,S       RESERVE WORKSPACE ON STACK
01648   3302       CLR    0,S       RESET NEGATIVE # FLAG
01649   3304       TSTA             CHECK FOR NEGATIVE #
01650   3306       BPL    QMUL1     NO
01651   3308       INC    0,S       SET NEGATIVE FLAG
01652   3310       COMA             1'S COMPLEMENT
01653   3312       COMB             1'S COMPLEMENT
01654   3314       ADDD   #1        2'S COMPLEMENT
01655   3316 QMUL1 STB    1,S       TEMP. SAVE 2'ND BYTE
01656   3318       LDB    6,S       MULTIPLIER
01657   3320       MUL
01658   3322       TFR    D,X
01659   3324       LDA    1,S       2'ND BYTE
01660   3326       LDB    6,S
01661   3328       MUL
01662   3330       LEAX   A,X       ADD RESULTS TOGETHER
01663   3332       STX    1,S       SAVE 24 BIT ANSWER
01664   3334       STB    3,S
01665   3336       TST    0,S       CHECK FOR NEGATIVE #
01666   3338       BEQ    QMUL2     NO
01667   3340       COM    1,S       COMPLEMENT 24 BITS
01668   3342       COM    2,S
01669   3344       COM    3,S
01670   3346       LDD    2,S
01671   3348       ADDD   #1        FORM 2'S COMPLEMENT
01672   3350       STD    2,S       SAVE COMPLEMENT
01673   3352       BCC    QMUL2
01674   3354       INC    1,S
01675   3356 QMUL2 LDA    1,S
01676   3358       STA    6,S       SAVE 4 MSB IN STACK ON RETURN
01677   3360       LDD    2,S       SAVE 16 LSB IN A,B REG
01678   3362       LEAS   4,S       CLEAN STACK
01679   3364       RTS
01680   3366       SPC    3
01681   3368 *
01682   3370 *     SUBROUTINE : QUICK DIVIDER
```

```
01683   3372 *          TRUE ROUND OFF OF (A,B)/2^DIVW
01684   3374 *            ENTERS WITH DIVISOR PRESAVED AT DIVW
01685   3376 *            DIVW+1 WORKSPACE
01686   3378 *           (A,B)  16 BIT SIGNED NUMBER
01687   3380 *
01688   3382 QDIV   CLR     DIVW+1    CLEAR WORKSPACE
01689   3384        TSTA                NEG NUMBER?
01690   3386        BPL     QDIV1     NO
01691   3388        INC     DIVW+1    SET NEGATIVE FLAG
01692   3390        BSR     COM16     2'S COMPLEMENT
01693   3392 QDIV1  ASRA
01694   3394        RORB                /2
01695   3396        DEC     DIVW
01696   3398        BGT     QDIV1
01697   3400        BCC     QDIV2
01698   3402        ADDD    #$01
01699   3404 QDIV2  TST     DIVW+1
01700   3406        BEQ     QDIV3
01701   3408        BSR     COM16
01702   3410 QDIV3  RTS
01703   3412        SPC     3
01704   3414 *
01705   3416 *     16 BIT 2'S COMPLEMENT OF (A,B)
01706   3418 *
01707   3420 COM16  COMA                1'S COMPLEMENT OF B MSB
01708   3422        COMB                1'S COMPLEMENT OF B LSB
01709   3424        ADDD    #$01        2'S COMPLEMENT OF 16 BITS
01710   3426        RTS
01711   3428        PAGE
01712   3430 *
01713   3432 *      ROUTINE TO INITIALIZE DISPLAY'S BIT PATTERNS
01714   3434 *
01715   3436 *       FOR BLANK DISPLAY-
01716   3438 *       & SETS PROPER SEQUENCE CODE TO BRACKET
01717   3440 *       SERIAL DATA ( START & FINISH )
01718   3442 *
01719   3444 *        INPUT: NONE
01720   3446 *        USES: Y,A
01721   3448 *        OUTPUTS: VFDATA(6)
01722   3450 *        RETURNS: "Y" REG POINTING TO VFDAT1
01723   3452 *
01724   3454 BDISP  LDY     #VFDATA   SET POINTER TO 1'ST DATA
01725   3456        LDA     #$A0
01726   3458        STA     0,Y       SET FINISH CODE
01727   3460        CLRA                BLANK ALL ACTIVE ELEMENTS
01728   3462        STA     1,Y
01729   3464        STA     2,Y
01730   3466        STA     3,Y
01731   3468        STA     4,Y
01732   3470        LDA     #$0A      SET START CODE
01733   3472        STA     5,Y
01734   3474        RTS
01735   3476        SPC     3
01736   3478 *
01737   3480 *      CONVERT 8 BIT BINARY VALUE A-REG.
01738   3482 *       TO 3 BCD VALUES AT
01739   3484 *       DNUM  DUM+1,DUM+2
01740   3486 *
```

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```
01741  3488 BCD     CLR    DNUM      CLEAR RESULT LOCATIONS
01742  3490         CLR    DNUM+1
01743  3492 BCD1    SUBA   #100
01744  3494         BCS    BCD2      LESS THAN 100
01745  3496         INC    DNUM      INCREMENT HUNDREDS DIGIT
01746  3498         BRA    BCD1
01747  3500 BCD2    ADDA   #100      RESTORE #
01748  3502 BCD3    SUBA   #10
01749  3504         BCS    BCD4      LESS THAN 10
01750  3506         INC    DNUM+1    INCREMENT TENS DIGIT
01751  3508         BRA    BCD3
01752  3510 BCD4    ADDA   #10       RESTORE #
01753  3512         STA    DNUM+2    SET ONE'S DIGIT
01754  3514         RTS
01755  3516         SPC    3
01756  3518 *
01757  3520 *     BCD TO BINARY CONVERSION
01758  3522 *       ENTERS A-REG WITH BCD NUMBER
01759  3524 *       EXITS A-REG WITH BINARY CONVERSION
01760  3526 *       AFFECTS NO OTHER REGISTERS
01761  3528 *
01762  3530 BINARY  PSHS   B
01763  3532         TFR    A,B       DUPLICATE A-REG
01764  3534         ANDB   #$0F      SEPERATE BCD DIGITS
01765  3536         ANDA   #$F0
01766  3538         PSHS   B         TEMPORARY SAVE
01767  3540         LDB    #160      X10 & SHIFT 4 POSITIONS
01768  3542         MUL
01769  3544         ADDA   S+        SUM LOWER DIGIT
01770  3546         PULS   B         RETRIEVE ORGINAL CONTENTS
01771  3548         RTS
01772  3550         PAGE
01773  3552 **
01774  3554 **    ERROR SUBROUTINE - SPECIAL FAULT DISPLAY
01775  3556 **
01776  3558 **      ENTER : 'B' REG. CONTAINING ERROR CODES
01777  3560 **      OUTPUTS : DISPLAYS FAULT CODE ON VFD
01778  3562 **      HALTS PROGRAM EXECUTION UNTIL FAULT IS ACKNOWLEDGED BY
01779  3564 **        DEPRESSING REMOTE DISPLAY PUSHBUTTON WHEREUPON EXECUTION
01780  3566 **        RETURNS & TRIES TO CONTINUE
01781  3568 **
01782  3570 ERROR   STB    FFLT      PRE-SET FAULT FLAG
01783  3572        LBSR   DISFLT
01784  3574        LBSR   CDISP
01785  3576 ERR1   LBSR   VFDIGP
01786  3578        LBSR   DIN1
01787  3580        LDB    .AXIN+1   REMOTE PUSHBUTTON DEPRESSED
01788  3582        BEQ    ERR1      NO
01789  3584        CLR    FFLT      RESET FAULT FLAG
01790  3586        CLR    DFLTC
01791  3588 ERR2   RTS
01792  3590        SPC    3
01793  3592 *
01794  3594 *     PIA INITIALIZATION SEQUENCE
01795  3596 *
01796  3598 *       PA0-PA3  DEVICE SELECT (OUT)
01797  3600 *
01798  3602 *       PA4-PA6  DATA,CLOCK,STROBE & BLANK (OUT)  REMOTE DISPLAY
```

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```
 1799   3604 *       PA7       SW1 (IN)  REMOTE DISPLAY
 1800   3606 *
01801   3608 *       CA1       TIMER INTERRUPT (IN) FIRQ
01802   3610 *       CA2       AREADY (OUT)
01803   3612 *                                                    ORIGINAL PAGE IS
01804   3614 *       PB0-PB7   CMOS DATA BUS (IN OR OUT)          OF POOR QUALITY
 1805   3616 *
01806   3618 *       CB1       ADC EOC (STATUS) - (IN) IRQ
 1807   3620 *       CB2       UNUSED
01808   3622 PIAINT  LDB     #PIABDR
01809   3624         STB     PIA1BC    SELECT DATA DIRECTION REGISTER
01810   3626         LDA     #$FF      PB0-PB7, CONFIGURE AS OUTPUTS
 1811   3628         STA     PIA1BD
01812   3630         LDB     #PIABPR   CB1-INPUT  - IRQ ENABLED - CB2 (OUT) ="0"
01813   3632         STB     PIA1BC
01814   3634         LDA     PIA1BD    CLEAR IRQ FLAG
01815   3636         LDB     #PIAAPR   CA1 (IN)  - FIRQ ENABLED - CA2 (OUT) = "1"
01816   3638         STB     PIA1AC    SELECT PERIPHERAL REGISTER
01817   3640         LDA     #$7F      PA0-PA6="1" (BLANK DISPLAY)
01818   3642         STA     PIA1AD    PRE-SET OUTPUTS
01819   3644         STA     PIAXAD    DUPLICATE IN RAM
01820   3646         LDB     #PIAADR
01821   3648         STB     PIA1AC    SELECT DATA DIRECTION REGISTER
01822   3650         STA     PIA1AD    PA0-PA6 OUTPUTS ; PA7 INPUT
01823   3652         LDB     #PIAAPR
01824   3654         STB     PIA1AC    SELECT PERIPHERAL REG.
01825   3656         LDA     PIA1AD    CLEAR IRQ FLAG
01826   3658         RTS
01827   3660         PAGE
01828   3662 *
01829   3664 *      SYSTEM DIAGNOSTICS - SUBROUTINES
01830   3666 *
01831   3668 *
01832   3670 *      ROM TEST  CHECKSUM  13 CYCLES/BYTE
01833   3672 *
01834   3674 ROMTST LDX     #ROMS+3   1'ST ROM ADDRESS AFTER ID & CHECKSUM BYTES
01835   3676        CLRA
01836   3678 ROM1   EORA    0,X+
01837   3680        CMPX    #ROME+1   LAST ROM ADDRESS COMPLETED
01838   3682        BNE     ROM1      NO
01839   3684        CMPA    CKSUM     CHECKSUM VALID
01840   3686        BRA     ROM2      YES ****** TEMP. DEFEATED (BEQ NORMAL BRANC
01841   3688        LDB     #ERRROM   SET ERROR CODE
01842   3690        LBSR    ERROR
01843   3692 ROM2   RTS
01844   3694        SPC     3
01845   3696 *
01846   3698 *      TEST RAM BY TOGGLING ALL BITS & CHECKING FOR CHANGES 2040 BY
01847   3700 *
01848   3702 RAMTST LDX     #$0
01849   3704 RAM2   LDA     0,X
01850   3706        COM     0,X       COMPLEMENT RAM LOCATION
01851   3708        ADDA    0,X
01852   3710        CMPA    #$FF      CHECK FOR VALID RESULT
01853   3712        BEQ     RAM3      BYTE TEST O.K., NEXT LOCATION
01854   3714        LDB     #ERRRAM   SET ERROR CODE
01855   3716        LBSR    ERROR
01856   3718 RAM3   COM     0,X+      RETURN RAM TO ORIGINAL VALUE
```

```
01857   3720          CMPX    #$0800    CHECK 2048 BYTES
01858   3722          BNE     RAM2      NO
01859   3724          RTS
01860   3726          SPC     3
01861   3728 *
01862   3730 *      TEST REAL TIME CLOCK BY SEEING IF MILLISECOND COUNTER ADVANCE
01863   3732 *
01864   3734 CLKTST   LDX     #$0       RESET SOFTWARE COUNTER
01865   3736 CLK1     LDA     RTCCTS    READ CLOCK COUNTER
01866   3738          LDB     RTCSR     CHECK FOR VALID READ
01867   3740          BNE     CLK1      READ AGAIN
01868   3742          PSHS    A
01869   3744 CLK2     LEAX    1,X
01870   3746          CMPX    #90       11 CYCLES @ 3.58 MHZ
01871   3748          BNE     CLK2      WAIT 1.1mS
01872   3750 CLK2A    LDB     RTCCTS    READ COUNTER AGAIN
01873   3752          LDA     RTCSR     CHECK FOR VALID READ
01874   3754          BNE     CLK2A     NO READ AGAIN
01875   3756          CMPB    0,S+      DID CLOCK ADVANCE?
01876   3758          BNE     CLK3      YES
01877   3760          LDB     #ERRCLK   SET ERROR CODE
01878   3762          LBSR    ERROR
01879   3764 CLK3     RTS
01880   3766          SPC     3
01881   3768 *
01882   3770 *  TEST RAM & CLOCK NON-VOLATILITY AUX. POWER
01883   3772 *
01884   3774 PWRTST   LDA     #$55      TEST VALUE
01885   3776          TST     FCAL      CALIBRATE REQUESTED
01886   3778          BNE     PWR2      YES
01887   3780          CMPA    RAMS      TEST BOTTOM OF MEMORY
01888   3782          BNE     PWR1      FAILED
01889   3784          CMPA    RAME      TEST TOP OF MEMORY
01890   3786          BEQ     PWR3
01891   3788 PWR1     LDB     #ERRPWR
01892   3790          LBSR    ERROR     DISPLAY FAULT
01893   3792          BRA     PWR2A     CONTINUE BUT DON'T RESET
01894   3794 PWR2     STA     RAMS      SET KNOWN TEST VALUE
01895   3796          STA     RAME
01896   3798 PWR2A    LDA     #$FF
01897   3800          STA     DEFLT     SET DEFAULT FLAG
01898   3802          STA     RTCCRE    RESET CLOCK
01899   3804 PWR3     RTS
01900   3806          SPC     3
01901   3808 *
01902   3810 *  PIA TEST SEQUENCE - AS CONFIGURED IN BCSCI
01903   3812 *     NOTE: B SIDE MUST BE PRESET TO BE OUTPUTS UPON ENTRY
01904   3814 *
01905   3816 PIATST   LDA     PIA1AD
01906   3818          BITA    #$80      TEST A SIDE INPUTS
01907   3820          BNE     PIA1      OK
01908   3822          LDB     #ERRPIA
01909   3824          LBSR    ERROR     DISPLAY ERROR CODE
01910   3826          LDA     PIA1AD
01911   3828 PIA1     COM     PIA1AD    TOGGLE A OUTPUTS
01912   3830          ADDA    PIA1AD
01913   3832          COM     PIA1AD    RETURN OUTPUTS TO ORIGINAL STATES
01914   3834          ANDA    #$7F      TEST OUTPUTS B0-B6
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01915  3836          CMPA   #$7F      OUTPUTS TOGGLED
01916  3838          BEQ    PIA2      O.K.
01917  3840          LDB    #ERRPOA
01918  3842          LBSR   ERROR
01919  3844 PIA2     LDA    #PIABDR
01920  3846          STA    PIA1BC
01921  3848          LDB    #$FF
01922  3850          STB    PIA1BD    CONFIGURE B SIDE AS OUTPUTS
01923  3852          LDA    #PIABPR
01924  3854          STA    PIA1BC
01925  3856          LDA    PIA1BD
01926  3858          COM    PIA1BD    TOGGLE B DATA REG.
01927  3860          ADDA   PIA1BD
01928  3862          CMPA   #$FF      REGISTER TOGGLES
01929  3864          BEQ    PIA3      YES
01930  3866          LDB    #ERRPOB
01931  3868          LBSR   ERROR
01932  3870 PIA3     LDA    #PIABDR   CONFIGURE B SIDE AS INPUTS
01933  3872          STA    PIA1BC
01934  3874          CLR    PIA1BD
01935  3876          LDA    #PIABPR
01936  3878          STA    PIA1BC
01937  3880          LDA    PIA1BD
01938  3882          CMPA   #$FF      B INPUTS PULLED HIGH
01939  3884          BEQ    PIA4      YES
01940  3886          LDB    #ERRPIB
01941  3888          LBSR   ERROR
01942  3890 PIA4     RTS
01943  3892          SPC    3
01944  3894 *
01945  3896 *  TEST ANALOG TO DIGITAL CONVERTER
01946  3898 *
01947  3900 ADCTST   LDD    TEST$,U   2.5 V TEST REFERENCE
01948  3902          CMPD   #2675     UPPER LIMIT
01949  3904          BGT    ADC1      OUT OF RANGE
01950  3906          CMPD   #2325     LOWER LIMIT
01951  3908          BGT    ADC2      OK
01952  3910 ADC1     LDB    #ERRADC   SET ERROR CODE
01953  3912          LBSR   ERROR
01954  3914 ADC2     RTS
01955  3916          SPC    3
01956  3918 *
01957  3920 *  TEST THERMISTOR INPUTS - FOR OPENS OR SHORTS
01958  3922 *
01959  3924 TMPTST   LDX    #TBLTOS   SET POINTER TO 1ST TABLE LOCATION
01960  3926 TMP1     LDA    0,X       READ VARIABLE OFFSET
01961  3928          LDD    A,U       READ VARIABLE
01962  3930          CMPD   #50       TEST FOR SHORTS
01963  3932          BGT    TMP2      O.K.
01964  3934          LDB    1,X       FETCH ERROR CODE FROM TABLE
01965  3936          PSHS   X         SAVE TABLE POINTER
01966  3938          LBSR   ERROR     DISPLAY SHORTED ERROR CODE
01967  3940          BRA    TMP3      TEST NEXT INPUT
01968  3942 TMP2     SUBD   TREF$,U
01969  3944          CMPD   #-50      TEST FOR OPENS
01970  3946          BLT    TMP4      O.K.
01971  3948          LDB    2,X       FETCH ERROR CODE FROM TABLE
01972  3950          PSHS   X
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01973   3952          LBSR    ERROR     DISPLAY OPEN ERROR CODE
01974   3954 TMP3     PULS    X         RETRIEVE LAST POINTER LOCATION
01975   3956 TMP4     LEAX    3,X       NEXT TABLE ENTRY
01976   3958          CMPX    #TBLTOE   TEST FOR LAST ENTRY
01977   3960          BLS     TMP1
01978   3962          RTS
01979   3964          SPC     3
01980   3966 *
01981   3968 *  SOFTWARE TRAP - MACRO
01982   3970 *
01983   3972 *
01984   3974 TRAP     MACR
01985   3976          SWI
01986   3978          SWI
01987   3980          SWI
01988   3982          ENDM
01989   3984          PAGE
01990   3986 **
01991   3988 **     TABLE
01992   3990 **       MULTIPLEXER SEQUENCING FOR EACH OPERATING MODE
01993   3992 **
01994   3994 **       1ST BYTE - OFFSET TO STORAGE LOCATION FOR EACH
01995   3996 **                  ANALOG INPUT
01996   3998 **
01997   4000 **       2ND BYTE - MULTIPLEXER ADDRESS FOR EACH ANALOG INPUT
01998   4002 **
01999   4004 *
02000   4006 *    CHARGE MODE
02001   4008 *
02002   4010 MUXCHG FDB     IBAT
02003   4012          FDB     VBAT.
02004   4014          FDB     ILINE.
02005   4016          FDB     TBAT.
02006   4018          FDB     IBAT.
02007   4020          FDB     VBAT.
02008   4022          FDB     ILINE.
02009   4024          FDB     TENC.
02010   4026          FDB     IBAT.
02011   4028          FDB     VBAT.
02012   4030          FDB     ILINE.
02013   4032          FDB     TFET.
02014   4034          FDB     END.
02015   4036 *
02016   4038 *    DISCHARGE MODE
02017   4040 *
02018   4042 MUXDIS FDB     IBAT.
02019   4044          FDB     VBAT.
02020   4046          FDB     IBAT.
02021   4048          FDB     TBAT.
02022   4050          FDB     IBAT.
02023   4052          FDB     TENC.
02024   4054          FDB     END.
02025   4056 *
02026   4058 *    REST MODE
02027   4060 *
02028   4062 MUXRST FDB     VBAT.
02029   4064          FDB     TBAT.
02030   4066          FDB     TENC
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02031   4068          FDB     END.
02032   4070 *
02033   4072 *    THINK MODE
02034   4074 *
02035   4076 MUXTHK FDB     TENC.
02036   4078          FDB     END.
02037   4080 *
02038   4082 *     DIAGNOSTIC MODE
02039   4084 *
02040   4086 MUXDIA FDB     TREF.
02041   4088          FDB     TFET.
02042   4090          FDB     TENC.
02043   4092          FDB     TAMB.
02044   4094          FDB     TBAT.
02045   4096          FDB     TEST.
02046   4098          FDB     END.
02047   4100          PAGE
02048   4102 **
02049   4104 **     TABLES : SELECT MODE LOOK-UP
02050   4106 **
02051   4108 **      0 PTR TO EXECUTIVE/MPL MODE ROUTINE
02052   4110 **      FOR PTR TO FORTRAN ROUTINE
02053   4112 **      ADC PTR TO MULTIPLEXER TABLE
02054   4114 **      DISP1 NORMAL DISPLAY
02055   4116 **      DISP2 OPTIONAL DISPLAY ( SW1 DEPRESSED )
02056   4118 **
02057   4120 FOR     EQU     2          ADDRESS OF FORTRAN ROUTINE
02058   4122 ADC     EQU     4          ADDRESS OF MULTIPLEXER TABLE
02059   4124 DISP1   EQU     6
02060   4126 DISP2   EQU     8
02061   4128 *
02062   4130 *      CHARGE MODE
02063   4132 *
02064   4134 TBLCHG FDB     CHGMPL
02065   4136          FDB     CHGFOR
02066   4138          FDB     MUXCHG
02067   4140          FDB     $000F      BLANK - VFD ; ENABLE - LED'S
02068   4142          FDB     $C50F      AC ON, WARNING, BAR, GRID - VFD; ENABLE LEI
02069   4144 *
02070   4146 *      DISCHARGE MODE
02071   4148 *
02072   4150 TBLDIS FDB     DISCHG
02073   4152          FDB     DISFOR
02074   4154          FDB     MUXDIS
02075   4156          FDB     $0500      BARGRAPH - VFD ; BLANK LED
02076   4158          FDB     $0300      NUMERIC - VFD ; BLANK LED
02077   4160 *
02078   4162 *     REST MODE
02079   4164 *
02080   4166 TBLRST FDB     REST
02081   4168          FDB     RSTFOR
02082   4170          FDB     MUXRST
02083   4172          FDB     $0008      BLANK - VFD ; BLANK - LED ; ALLOW FAULT
02084   4174          FDB     $0508      BARGRAPH - VFD ; BLANK - LED ; ALLOW FAULT
02085   4176 *
02086   4178 *      THINK MODE
02087   4180 *
02088   4182 TBLTHK FDB     THINK
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02089   4184          FDB     THKFOR
02090   4186          FDB     MUXTHK
02091   4188          FDB     $0008     BLANK - VFD ; BLANK - LED ; ALLOW FAULT
02092   4190          FDB     $0508     BARGRAPH - VFD ; BLANK - LED ; ALLOW FAULT
02093   4192 *
02094   4194 *      DIAGNOSTIC MODE - USED DURING INITIALIZATION ONLY
02095   4196 *
02096   4198 TBLDIA FDB     0
02097   4200          FDB     0
02098   4202          FDB     MUXDIA
02099   4204          FDB     0
02100   4206          FDB     0
02101   4208          PAGE
02102   4210 **                                                    a
02103   4212 **     TABLE: BINARY TO SEVEN SEGMENT DECODER      f   b
02104   4214 **     BIT7-0   0sfedcba  SEGMENT DESIGNATION        s
02105   4216 **                                                 e   c
02106   4218 **                                                   d
02107   4220 **
02108   4222 TBLNUM FCB     %00111111 (0) 0
02109   4224          FCB     %00000110 (1) 1
02110   4226          FCB     %01011011 (2) 2
02111   4228          FCB     %01001111 (3) 3
02112   4230          FCB     %01100110 (4) 4
02113   4232          FCB     %01101101 (5) 5
02114   4234          FCB     %01111101 (6) 6
02115   4236          FCB     %00000111 (7) 7
02116   4238          FCB     %01111111 (8) 8
02117   4240          FCB     %01100111 (9) 9
02118   4242          FCB     %01000000 (A) -
02119   4244          FCB     %00000000 (B)
02120   4246          FCB     %00000000 (C)
02121   4248          FCB     %00000000 (D)
02122   4250          FCB     %00000000 (E)
02123   4252          FCB     %00000000 (F) BLANK
02124   4254          SPC     3
02125   4256 **
02126   4258 **     TABLE . BAR-GRAPH PERCENT STATE OF CHARGE
02127   4260 **
02128   4262 **
02129   4264 TBLBAR FDB     $0400     0%
02130   4266          FDB     $0401     10%
02131   4268          FDB     $0403     20%
02132   4270          FDB     $0407     30%
02133   4272          FDB     $040F     40%
02134   4274          FDB     $041F     50%
02135   4276          FDB     $043F     60%
02136   4278          FDB     $047F     70%
02137   4280          FDB     $04FF     80%
02138   4282          FDB     $05FF     90%
02139   4284 TBLBAE FDB     $07FF     100%
02140   4286          SPC     3
02141   4288 **
02142   4290 **     TABLE : TEST DISPLAY SEQUENCE
02143   4292 **
02144   4294 **      2-BYTE ADDRESS OF VARIABLE LOCATION
02145   4296 **
02146   4298 **      MAXIMUM LENGTH, TEN CHARACTERS
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```
02147   4300 **
02148   4302 **
02149   4304 TBLTST FDB     ID
02150   4306        FDB     VBAT
02151   4308        FDB     VBAT+1
02152   4310        FDB     VLIM
02153   4312        FDB     VLIM+1
02154   4314        FDB     AMPH
02155   4316        FDB     AMPH+1
02156   4318        FDB     IBAT
02157   4320        FDB     IBAT+1
02158   4322 TBLTSE FDB     FMODE+1
02159   4324        SPC     3
02160   4326 **
02161   4328 **     TIME TABLE: USED BY TIME ROUTINE TO ADVANCE COUNTERS
02162   4330 **         ENTRIES ARE ADDRESSES OF COUNTERS
02163   4332 **         TO BE ADVANCED
02164   4334 **
02165   4336 TBLTIM FDB     EQUTIM
02166   4338        FDB     DISTIM
02167   4340        FDB     CHGTIM
02168   4341 TBLTIE FDB     IDATIM
02169   4342        PAGE
02170   4344 **
02171   4346 **     TABLE OF THERMISTOR LIMITS
02172   4348 **      1'ST BYTE - OFFSET TO VARIABLE ADDRESS STORAGE LOCATION
02173   4350 **      2'ND BYTE - FIRST LIMIT CAUSES FAULT INDICATION.
02174   4352 **      3'RD BYTE - SECOND LIMIT CAUSES POWER STAGE TO BE DISABLED
02175   4354 **
02176   4356 TBLTEM FCB     TBAT$     THERMISTOR - BATTERY ELECTROLYTE
02177   4358        FDB     1060      50 C
02178   4360        FDB     0
02179   4362        FCB     ERRTBA
02180   4364        FCB     TENC$     THERMISTOR - MAIN ENCLOSURE
02181   4366        FDB     696       65 C
02182   4368        FDB     596       70 C
02183   4370        FCB     ERRTEN
02184   4372        FCB     TFET$     THERMISTOR - FET HEATSINK
02185   4374        FDB     521       75 C
02186   4376        FDB     446       80 C
02187   4378        FCB     ERRTFE
02188   4380        FCB     TAMB$     THERMISTOR - BATTERY AMDIENT
02189   4382        FDB     596       70 C
02190   4384        FDB     0
02191   4386 TBLTEE FCB     ERRTAM
02192   4388        SPC     3
02193   4390 **
02194   4392 **     THERMISTOR ERROR CODE TABLE
02195   4394 **      1ST BYTE OFFSET TO VARIABLE STORAGE LOCATION
02196   4396 **      2ND BYTE SHORTED ERROR CODE
02197   4398 **      3RD BYTE OPEN ERROR CODE
02198   4400 **
02199   4402 TBLTOS FCB     TBAT$,ERRTBS,ERRTBO
02200   4404        FCB     TENC$,ERRTES,ERRTEO
02201   4406        FCB     TFET$,ERRTFS,ERRTFO
02202   4408 TBLTOE FCB     TAMB$,ERRTAS,ERRTAO
02203   4410        SPC     3
02204   4412 **
```

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```
02205   4414 **     TABLE LOOK-UP:
02206   4416 **       THERMISTOR LINEARIZATION
02207   4418 **       SIERRAN-WESTERN #1M1002-A2
02208   4420 **       VREF=4.000 V  ; R=10K BIASING
02209   4422 **       OFFSET BY 40 C
02210   4424 **
02211   4426 TBLTHE FCB     185       145 C (0.00V) ACTUAL TEMPERATURE
02212   4428        FCB     140       100 C (.256V)
02213   4430        FCB     115       75 C  (.512V)
02214   4432        FCB     101       61 C  (.768V)
02215   4434        FCB     91        51 C  (1.024V)
02216   4436        FCB     83        43 C  (1.280V)
02217   4438        FCB     76        36 C  (1.536V)
02218   4440        FCB     70        30 C  (1.792V)
02219   4442        FCB     64        24 C  (2.048V)
02220   4444        FCB     58        18 C  (2.304V)
02221   4446        FCB     52        12 C  (2.560V)
02222   4448        FCB     46        6 C   (2.816V)
02223   4450        FCB     40        0 C   (3.072V)
02224   4452        FCB     32        -8 C  (3.328V)
02225   4454        FCB     22        -18 C (3.584V)
02226   4456        FCB     5         -35 C (3.840V)
02227   4458        FCB     0         -40 C (4.096V) "OFF SCALE"
02228   4460        PAGE
02229   4462 **
02230   4464 **     EQUATE TABLE OF SYSTEM ERROR CODES
02231   4466 **
02232   4468 **       4 MSB PRIMARY - ASSEMBLY NUMBER
02233   4470 **       4 LSB SECONDARY - ERROR WITHIN ASSEMBLY
02234   4472 **
02235   4474 *    NOTE:      $0X       INDICATES RUN TIME FAULTS CHECK MPL LISTING
02236   4476 *
02237   4478 ERRPWR EQU     $11       AUX. - POWER DEFECTIVE - RAM, TIME INFO. LOS
02238   4480 *
02239   4482 ERRCHG EQU     $21       POWER STAGE FAULT USED INLMPL
02240   4484 *
02241   4486 ERRADC EQU     $31       A/D CONVERSION INVALID
02242   4488 ERROF  EQU     $32       A/D OVERFLOW INDICATION
02243   4490 ERRNEG EQU     $33       ANALOG INPUT INCORRECT POLARITY
02244   4492 ERRSM1 EQU     $34       SELECT MODE - INVALID MODE
02245   4494 *
02246   4496 ERRROM EQU     $41       ROM CHECKSUM ERROR
02247   4498 ERRRAM EQU     $42       BITS IN RAM WILL NOT TOGGLE
02248   4500 ERRCIO EQU     $43       1/SEC INTERRUPT
02249   4502 ERRCLK EQU     $44       REAL TIME CLOCK DOESN'T ADVANCE
02250   4504 ERRPIA EQU     $45       PIA A INPUT FAULT
02251   4506 ERRPIB EQU     $46       PIA B INPUT FAULT
02252   4508 ERRPOA EQU     $47       PIA A OUTPUT FAULT
02253   4510 ERRPOB EQU     $48       PIA B OUTPUT FAULT (INTERNAL)CHECK ONLY)
02254   4512 *
02255   4514 ERRTBS EQU     $70       BATTERY THERMISTOR SHORTED
02256   4516 ERRTES EQU     $71       ENCLOSURE THERMISTOR SHORTED
02257   4518 ERRTFS EQU     $72       FET THERMISTOR SHORTED
02258   4520 ERRTAS EQU     $73       AMBIENT THERMISTOR SHORTED
02259   4522 ERRTBO EQU     $75       BATTERY THERMISTOR OPEN OR FUSE BLOWN
02260   4524 ERRTEO EQU     $76       ENCLOSURE THERMISTOR OPEN
02261   4526 ERRTFO EQU     $77       FET THERMISTOR OPEN OR FUSE BLOWN
02262   4528 ERRTAO EQU     $78       AMBIENT THERMISTOR OPEN OR FUSE BLOWN
```

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02263   4530 *
02264   4532 ERRTBA EQU   $81      BATTERY OVERTEMP.
02265   4534 ERRTEN EQU   $82      ENCLOSURE OVERTEMP.
02266   4536 ERRTFE EQU   $83      FET OVERTEMP.
02267   4538 ERRTAM EQU   $84      AMBIENT OVERTEMP.
02268   4540 *
02269   4542 ERRBAT EQU   $91      BAT. BELOW MIN. VALUE
02270   4544 ERRFPI EQU   $92      INVALID SWITCH SETTING
02271   4546 ERRSOF EQU   $93      SPEED TRANSDUCER CALIBRATION ERROR
02272   4548 ERRSHI EQU   $94      SPEED COUNTER OVERFLOW
02273   4550 ERR    EQU   $99
02274   4552        END
```

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```
00001    C       VEQ                 Motorola-6809                 ndh: 27-Sep-82
00002    C
00003    C Written by -          Neil D. Herbert                   08-Sep-82
00004    C                  GLEER Computer & Software Systems
00005    C                  Gould, Inc., Rolling Meadows, Ill.
00006    C                  312/640-4472
00007    C
00008    C Modifications:
00009    C
00010    C       Replaced some integer variables with real in COMMON.
00011    C       Added some constants to the COMMON.
00012    C              Neil D. Herbert              13-Sep-82        ndh-010
00013    C
00014    C       Edited for Motorola-6809.
00015    C              Neil D. Herbert              27-Sep-82        ndh-020
00016    C
00017    C       ********************************************************************
00018    C              Equilibrium Voltage        Ver 2.0
00019    C       ********************************************************************
00020    C
00021    C Description:
00022    C       Calculates equilibrium voltage based on
00023    C       state of charge and temperature
00024    C
00025    C Inputs:        Battery state of charge and temperature.
00026    C
00027    C Outputs.       Expected equilibrium voltage of battery
00028    C
00029    C Subprograms called:        (none)
00030    C
00031    C                                                    ORIGINAL PAGE IS
00032    C                                                    OF POOR QUALITY
00033          FUNCTION VEQ(QBAT,TBAT)
00034    $H    VEQ
00035    C
00036    C Arguments:        QBAT        = Battery state of charge
00037    C                   TBAT        = Battery temperature
00038    C
00039    C
00040    C Declarations:
00041    C
00042    C                                                    ndh-010 begin
00043          COMMON                IFMODE,IWAKEF,IVLIN,IFINI
00044          COMMON                IIBAT,IVBAT,ITBAT,ISPEED
00045          COMMON                AMPSF,TEMPF,PWRF,SPDF
00046          COMMON                IQBAT,IQBATX,IQLAST,IQABS
00047          COMMON                IFRST,IFCHG,IFTHR                ,ndh-020
00048          COMMON                IFEQU,IRESET,ISFCAL
00049          COMMON                IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00050          COMMON                R1(4,3),R2(4,3),Q2(4,3)
00051          COMMON                RK1,RK2,RK3,RK4
00052          COMMON                VEQ1,VEQ2,VEQ3,VEQ4
00053          COMMON                BCFQ,BCFV,BCFTIM
00054    C                                                  ,ndh-010 end
00055          COMMON                IDATIM,IIQ,IFEMA                 ,mod 5 alter
00056          COMMON                M,JD,JL,IVALID
00057          COMMON                DTEMP(2),DRDEL(6)
00058          COMMON                DVBAT(9),DAMPF(2),DQBAT(9)
```

```
00059          COMMON                  VDELF,VDELQ,VDELT,VERRT
00060          COMMON                  RDEL,THELTA,TEMP,QCOR
00061          COMMON                  PWR,AMFS,THELTB,IQX                ;mod.5 end
00062    C
00063    C Main Body:
00064    C
00065          VEQ=(VEQ1+VEQ2*TBAT)+(VEQ3+VEQ4*TBAT)*QBAT
00066          RETURN
00067          END
```

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OF POOR QUALITY

```
PAGE 001  INIFOR  .SA:1

00001    C       INIFOR                  Motorola-6809                   ndh:29-Sep-82
00002    C
00003    C Written by -          Neil D. Herbert                 29-Sep-82
00004    C                  Computer & Software Systems
00005    C                  Gould Electronics Laboratory
00006    C                  Gould, Inc., Rolling Meadows, Ill
00007    C                  312/640-4472
00008    C
00009    C Modifications:
00010    C5      Changes incorporated to accomplish mod 5 parameter adaptor
00011    C5      algorithm;              Robert T. Calvert  5-Mar-84
00012    C5           1) Added five lines of COMMON following line 'COMMON   BCF(
00013    C5              BCFV,BCFTIM'.
00014    C5                              Identifier definitions;
00015    C5                                IDATIM - time since last data collectior
00016    C5                                IIQ - redifined equalize flag.
00017    C5                                IFEMA - flag for adaptor error
00018    C5                                        minimization routine.
00019    C5                                M - pointer for first valid data point.
00020    C5                                JD - last data point taken.
00021    C5                                JL - pointer for last valid data point.
00022    C5                                IVALID - flag for passing data validity
00023    C5                                         test.
00024    C5                                DTEMP(2) - data recorded - battery temp.
00025    C5                                DRDEL(9) - data recorded - impedance
00026    C5                                           error.
00027    C5                                DVBAT(9) - data recorded - battery
00028    C5                                           voltage.
00029    C5                                DAMPT(9) - data recorded - battery
00030    C5                                           current.
00031    C5                                DQBAT(9) - data recorded - charge
00032    C5                                           removed from battery.
00033    C5                                VDELF - voltage error averaged over QBA
00034    C5                                VDELQ - voltage error times QBAT.
00035    C5                                VDELT - voltage error averaged over QBA
00036    C5                                        and time.
00037    C5                                VERRT - voltage error after rest mode
00038    C5           2) Added seventeen lines to initialize variables following
00039    C5              line 'BCFTIM=2'
00040    C
00041    C
00042    C       ********************************************************
00043    C              Initialize Variables        Ver 0.0
00044    C       ********************************************************
00045    C
00046    C Description:
00047    C       If necessary, the battery voltage and temperature
00048    C       are used to determine the state of charge.
00049    C
00050    C Inputs:       Battery voltage & temperature.
00051    C
00052    C Outputs:       Corrected Amp-hour meter value.
00053    C
00054    C Subprograms called:       VEQ
00055    C
00056    C
00057           SUBROUTINE INIFOR
00058    9H    INIFOR
```

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OF POOR QUALITY

```
00059    C
00060    C Arguments:          (none)
00061    C
00062    C Standard Formats:
00063    C
00064    C Declarations:
00065    C
00066          COMMON                IFMODE,IWAKEF,IVLIM,IFINI
00067          COMMON                IIBAT,IVBAT,ITBAT,ISPEED
00068          COMMON                AMPSF,TEMPF,PWRF,SFDF
00069          COMMON                IQBAT,IQBATX,IQLAST,IQABS
00070          COMMON                IFRST,IFCHG,IFTHK
00071          COMMON                IFEQU,IRESET,ISPCAL
00072          COMMON                IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00073          COMMON                R1(4,3),R2(4,3),Q2(4,3)
00074          COMMON                RK1,RK2,RK3,RK4
00075          COMMON                VEQ1,VEQ2,VEQ3,VEQ4
00076          COMMON                BCFQ,BCFV,BCFTIM
00077          COMMON                IDATIM,IIQ,IFEMA                    ;mod 5 start
00078          COMMON                M,JD,JL,IVALID
00079          COMMON                DTEMP(2),DRDEL(9)
00080          COMMON                DVBAT(9),DAMPF(9),DQDAT(9)
00081          COMMON                VDELF,VDELQ,VDELT,VERRT
00082          COMMON                RDEL,THELTA,TEMF,QCOR
00083          COMMON                PWR,AMPS,THELTB,IQX                 ;mod 5 end
00084    C
00085    C Function Definitions:
00086    C
00087    C Main Body:
00088    C
00089    C Assign initial values to COMMON variables
00090          ISPCAL=1745
00091          R1(1,1)=2.7293E-3
00092          R1(2,1)=1.8232E-3
00093          R1(3,1)=1.6044E-3
00094          R1(4,1)=1.6320E-3
00095          R1(1,2)=2.9568E-3
00096          R1(2,2)=1.7384E-3
00097          R1(3,2)=1.5260E-3
00098          R1(4,2)=1.2800E-3
00099          R1(1,3)=2.2395E-3
00100          R1(2,3)=1.3714E-3
00101          R1(3,3)=1.3090E-3
00102          R1(4,3)=1.2854E-3
00103          R2(1,1)=0.5070E-3
00104          R2(2,1)=0.2137E-3
00105          R2(3,1)=0.1190E-3
00106          R2(4,1)=0.0940E-3
00107          R2(1,2)=0.3792E-3
00108          R2(2,2)=0.1732E-3
00109          R2(3,2)=0.1216E-3
00110          R2(4,2)=0.1000E-3
00111          R2(1,3)=0.2180E-3
00112          R2(2,3)=0.1794E-3
00113          R2(3,3)=0.1331E-3
00114          R2(4,3)=0.1175E-3
00115          Q2(1,1)=-125.88
00116          Q2(2,1)= -83.00
```

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```
00117           Q2(3,1)= -69.35
00118           Q2(4,1)= -70.72
00119           Q2(1,2)=-164.46
00120           Q2(2,2)=-109.40
00121           Q2(3,2)= -91.88
00122           Q2(4,2)= -84.80
00123           Q2(1,3)=-188.86
00124           Q2(2,3)=-141.35
00125           Q2(3,3)=-121.07
00126           Q2(4,3)= -98.24
00127           RK1=-.006884                    ;-.050/(30bit/hr*0.2421A.hr/bit)
00128           RK3=-2.16                      ;-2mv/cell/deg.C*(54cells/.050v/bit)
00129           RK4=-10.33                      ;2.5% of nominal 100A Hr capacity
00130           VEQ1=2.161                      ;volts/cell
00131           VEQ2=-5.16E-4                     ;volts/cell/deg.C
00132           VEQ3=1.217E-3                     ;volts/cell/A.hr
00133           VEQ4=-7.42E-6                     ;volts/cell/A.hr/deg.C
00134           BCFQ=0.2421                     ;A.Hr/bit
00135           BCFV=0.926E-3                     ;volts/cell/bit
00136           BCFTIM=2.                      ;minutes/bit
00137            VERR=0.0                       ;mod.5 start
00138            VDELF=0.0
00139            VDELQ=0.0
00140            VDELT=0.0
00141            IFEMA=0
00142            IIQ=0
00143            IQX=0
00144            IVALID=0
00145            IDATIM=0
00146            DTEMP(1)=0.0
00147            DTEMP(2)=0.0
00148            JD=0
00149            M=0
00150            JL=0
00151            VERR=0.0
00152            VERRT=0.0
00153            DO 200 I=1,9
00154              DRDEL(I)=0.0
00155              DVBAT(I)=0.0
00156              DAMPF(I)=0.0
00157              DQBAT(I)=0.0
00158   200        CONTINUE                     ;mod.5 end
00159   C
00160   C
00161   C If adjustment not specified, skip it
00162           IF(IFCHG.LE.0)  GOTO 900
00163   C
00164   C Convert and Scale "Integer" data to "Real"
00165             VBAT=IVBAT*BCFV
00166             TBAT=ITBAT                    ;1deg.C/bit
00167             QBAT=IQBAT*BCFQ
00168   C
00169   C Calculate Equilibrium Voltage & Voltage Error
00170             VERR=VBAT-VEQ(QBAT,TBAT)
00171   C
00172   C If Voltage Error <= 5mv/cell then skip correction
00173             IF(ABS(VERR).LE.0.005)  GOTO 900
00174   C
```

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```
00175    C Correct A.hr meter
00176                 QBAT=QBAT+1.0*VERR/(VEQ3+VEQ4*TBAT)
00177                 IQBAT=QBAT/BCFQ
00178    C
00179    900        CONTINUE
00180    C Return Control To Executive
00181           RETURN
00182           END
```

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```
00001    C        RSTFOR                  Motorola-6809                  ndh: 27-Sep-82
00002    C
00003    C Written by -         Neil D. Herbert                  26-Aug-82
00004    C                  Computer & Software Systems
00005    C                  Gould Electronics Laboratory
00006    C                  Gould, Inc., Rolling Meadows, Ill.
00007    C                  312/640-4472
00008    C
00009    C Modifications:
00010    C        Added more COMMON as needed for DISFOR.
00011    C                  Neil D. Herbert                  03-Sep-82        ndh-001
00012    C
00013    C        Made calculation of VEQ an external function.
00014    C                  Neil D. Herbert                  08 Sep-82        ndh-002
00015    C
00016    C        Replaced some inteser variables with real in COMMON.
00017    C        Corrections from J. Mezera
00018    C        Added some constants to the COMMON.
00019    C                  Neil D  Herbert                  13-Sep-82        ndh-010
00020    C
00021    C        Edited for Motorola-6809.
00022    C                  Neil D  Herbert                  27-Sep-82        ndh-020
00023    C
00024    C        ********************************************************************
00025    C                  Rest Monitor         Ver 2 0
00026    C        ********************************************************************
00027    C
00028    C Description.
00029    C        After a 2-hour rest, the battery voltage and temperature
00030    C        are used to determine the state of charge
00031    C        1/2 the difference is then added to the Amp-hour meter.
00032    C
00033    C Inputs:          Battery voltage & temperature.
00034    C
00035    C Outputs:          Corrected Amp-hour meter value.
00036    C
00037    C Subprograms called.          VEQ
00038    C
00039    C
00040          SUBROUTINE FSTFOR
00041    $H    RSTFOR
00042    C
00043    C Arguments:          (none)
00044    C
00045    C Standard Formats:
00046    C
00047    C Declarations:
00048    C
00049    C                                                          ndh-010 begin
00050          COMMON                IFMODE,IWAKEF,IVLIM,IFINI
00051          COMMON                IIBAT,IVBAT,ITBAT,ISPEED
00052          COMMON                AMPSF,TEMPF,PWRF,SPDF
00053          COMMON                IQBAT,IQBATX,IQLAST,IQABS
00054          COMMON                IFRST,IFCHG,IFTHF                          ndh-020
00055          COMMON                IFEQU,IRESET,ISPCAL
00056          COMMON                IDSOC,IDMILE,IDCTIM,IEOTIM,ICGTIM
00057          COMMON                R1(4,3),R2(4,3),R2(4,3)
00058          COMMON                RK1,RK2,RK3,RK4
```

```
00059           COMMON                  VEQ1,VEQ2,VEQ3,VEQ4
00060           COMMON                  BCFQ,BCFV,BCFTIM
00061     C                                                             ;ndh-010 end
00062           COMMON                  IDATIM,IIQ,IFEMA              ;mod.5 start
00063           COMMON                  M,JD,JL,IVALID
00064           COMMON                  DTEMP(2),DRDEL(9)
00065           COMMON                  DVBAT(9),DAMPF(9),DUBAT(9)
00066           COMMON                  VDELF,VDELQ,VDELT,VERRT
00067           COMMON                  RDEL,THELTA,TEMP,QCOR
00068           COMMON                  PWR,AMPS,THELTB,IQX           ;mod.5 end
00069     C
00070     C                                                             ;ndh-020
00071     C
00072     C Function Definitions:
00073     C
00074     C Main Body:
00075     C
00076     C Convert and Scale "Inteser" data to "Real"
00077           VBAT=IVBAT*BCFV                                         ;ndh-010,020
00078           TBAT=ITBAT                ;1des.C/bit
00079           QBAT=IQBAT*BCFQ                                         ;ndh-010,020
00080     C
00081     C Calculate Equilibrium Voltage & Voltage Error
00082           VERR=VBAT-VEQ(QBAT,TBAT)                                ;ndh-001
00083     C
00084     C If Votltage Error <= 5mv/cell then skip correction
00085           IF(ABS(VERR).LE.0.005)  GOTO 900
00086     C
00087     C Correct A.hr meter
00088             QBAT=QBAT+0.5*VERR/(VEQ2+VEQ1*TBAT)
00089             IQBAT=QBAT/BCFQ                                       ;ndh-010
00090     C
00091     900      CONTINUE
00092     C Return Control To Executive
00093           IFRST=0                 ;REST cycle completed           ;ndh-010
00094           IFMODE=-1
00095           RETURN
00096           END
```

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```
00001   C       CHGFOR                  Motorola-6809                   ndh:27-Sep-82
00002   C
00003   C Written by -          Neil D. Herbert                 26-Aug-82
00004   C                       Computer & Software Systems
00005   C                       Gould Electronics Laboratory
00006   C                       Gould, Inc., Rolling Meadows, Ill.
00007   C                       312/640-4472
00008   C
00009   C Modifications:
00010   C       Changed sign of IQBAT to --out of battery.
00011   C               Neil D. Herbert                 27-Aug-82       ndh-001
00012   C
00013   C       Modified Charge Acceptance algrithm.
00014   C               Neil D. Herbert                 30-Aug-82       ndh-002
00015   C
00016   C       Added adjustment of IQLAST for temperature.
00017   C       Assume none of the "over-charge" goes into the battery.
00018   C               Neil D. Herbert                 31-Aug-82       ndh-003
00019   C
00020   C       New Charge Correction.
00021   C               Neil D. Herbert                 31-Aug-82       ndh-004
00022   C
00023   C       Moved all correction code into charging loop
00024   C       to keep State-Of-Charge indicator up to date.
00025   C               Neil D. Herbert                 02-Sep-82       ndh-005
00026   C
00027   C       Added more COMMON as needed for DISFOR.
00028   C       Moved update of IQABS from DISFOR.
00029   C               Neil D. Herbert                 03-Sep-82       ndh-006
00030   C
00031   C       Changed function TEMPF to TEMPFN
00032   C       Replaced some integer variables with real in COMMON
00033   C       Corrections from J. Mezera.
00034   C       Added some constants to the COMMON
00035   C               Neil D. Herbert                 13-Sep-82       ndh-010
00036   C
00037   C       Edited for Motorola 6809
00038   C               Neil D. Herbert                 27-Sep-82       ndh-020
00039   C
00040   C
00041   C5      Changes incorporated to accomplish mod 5 parameter adaptor
00042   C5      algorithm.              Robert T. Calvert 6-Mar-84
00043   C5         1) Added five lines of COMMON after line 'COMMON     BCFO,
00044   C5            BCFV,BCFTIM'.
00045   C5         2) Added four lines after the line 'IQABS=IQABS-QDIS+
00046   C5            IQB4-IQSOC', which calculates the weighted average
00047   C5            voltage prediction error.
00048   C5         3) Added three lines after the line 'IF(IFEQU.NE.-1
00049   C5            .OR. IQBAT.LT.IQLIM) GO TO 600', to reset variables
00050   C5            after an equalization.
00051   C5         4) Added two lines following the line '900     CONTINUE',
00052   C5            which sets the THINK MODE flag.
00053   C
00054   C
00055   C       ************************************************************
00056   C               Charge Monitor          Ver 2.0
00057   C       ************************************************************
00058   C
```


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```
00059    C Description:
00060    C       Sets charging parameters.
00061    C       When charging done, sets battery Amp-hour meter value.
00062    C
00063    C Inputs:        Battery Amp-hour meter value.
00064    C                Battery temperature.
00065    C
00066    C Outputs:       Battery voltage limit during charge.
00067    C                New battery Amp-hour meter value.
00068    C
00069    C Subprograms called:        TEMPFN                              ;ndh-010
00070    C
00071    C
00072    C
00073          SUBROUTINE CHGFOR
00074    $H    CHGFOR
00075    C
00076    C Arguments:        (none)
00077    C
00078    C Standard Formats:
00079    C
00080    C Declarations:
00081    C
00082    C                                                    ;ndh-010 begin
00083          COMMON                  IFMODE,IWAKEF,IVLIM,IFINI
00084          COMMON                  IIBAT,IVBAT,ITBAT,ISPEED
00085          COMMON                  AMPSF,TEMPF,PWRF,SPDF
00086          COMMON                  IQBAT,IQBATX,IQLAST,IQABS
00087          COMMON                  IFRST,IFCHG,IFTHK              ;ndh-020
00088          COMMON                  IFEQU,IRESET,ISPCAL
00089          COMMON                  IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00090          COMMON                  R1(4,3),R2(4,3),Q2(4,3)
00091          COMMON                  RK1,RK2,RK3,RK4
00092          COMMON                  VEQ1,VEQ2,VEQ3,VEQ4
00093          COMMON                  BCFQ,BCFV,BCFTIM
00094    C                                                   ;ndh-010 end
00095          COMMON                  IDATIM,IIQ,IFENA               ;mod 5 start
00096          COMMON                  M,JD,JL,IVALID
00097          COMMON                  DTEMP(2),DRDEL(9)
00098          COMMON                  DVBAT(9),DAMPF(9),DQBAT(9)
00099          COMMON                  VDELF,VDELQ,VDELT,VEQRT
00100          COMMON                  RDEL,THELTA,TEMP,QCUR
00101          COMMON                  PWR,AMPS,THELTB,IQX            ;mod 5 end
00102    C
00103    C
00104    C Function Definitions:
00105    C
00106    C Main Body:
00107    C
00108          IQBAT=IQBAT+IDCTIM*RK1 ;Adjust for self-discharge ;ndh-020
00109          QDIS=IQLAST-IQBAT ;Total discharge      ;ndh-001
00110          IDCTIM=0      ;Reset Self-Discharge timer ;ndh-005
00111    C
00112    C
00113    C Begin Charging loop    +++++++++++++++++++++++++++++++++++++++++++++++++++++++
00114    200       CONTINUE
00115          IF(IFEQU.EQ.-1)  GOTO 220 ;Equalize Requested?
00116            IQEQU=0                ;   NO.
```

```
00117              RVREG=2646.0 ;2.45v/cell*54cells/.050v/bit      ;ndh-010
00118              GOTO 300
00119    220        CONTINUE                ;   YES.
00120              IQEQU=TEMPFN(ITBAT,74.3,49.6) ;12 to 18%       ;ndh-005,010
00121              RVREG=2916.0 ;2.70v/cell*54cells/.050v/bit      ;ndh-010
00122    C           .
00123    300        CONTINUE
00124    C Calculate Charge-IN Limits
00125              IQOVC=QDIS*TEMPFN(ITBAT,0.12,0.00)               ;ndh-010
00126              IQNLIM=IQLAST+IQOVC                              ;ndh-005
00127              IQLIM=IQNLIM+IQEQU                               ;ndh-005
00128    C Calculate & SET Voltage Limit
00129              IVLIM=RVREG+ITBAT*RK3                            ;ndh-020
00130    C
00131    C
00132    C
00133    C                                                         ;ndh-005 begin
00134              IQSOC=IQBAT     ;Update State-Of-Charge
00135    C
00136    C Calculate Charge Acceptance Point at current Temperature
00137              QACC=-TEMPFN(ITBAT,72.3,62.0) ;17.5-15.0% ;ndh-002,004,010,020
00138              IQB4=IQLAST*QACC/-62.0 ;Adjust for temperature ;ndh-003,020
00139    C
00140              IF(IQBAT.LE.QACC)  GOTO 400 ;If no adj. needed ;ndh-001,002,004
00141    C Calculate Amp-Hour Corrections
00142    C                                                         ;ndh-004 begin
00143                QCOR=(IQBAT-QACC)/(IQLIM-QACC)
00144                IQB4=IQB4+QCOR*RK4                             ;ndh-020
00145                IF(IQB4.LT.QACC)  IQB4=QACC ;Limit of IQLAST
00146    C
00147    C Correct Battery State-Of-Charge
00148              IF(IQLIM.GT.IQNLIM .AND.  IQBAT.GT.IQNLIM)
00149    &            IQB4=IQB4*(1.-(1.0*IQBAT-IQNLIM)/(IQLIM-IQNLIM)) ;ndh-020
00150    C                                                         ;ndh-005
00151              IQSOC=IQB4-(IQB4-QACC)*(1.-QCOR)
00152    C                                                         ;ndh-004 end
00153    400        CONTINUE
00154              IDSOC=10+(IQSOC-21)/41 ;Update State-Of-Charge Display
00155    C                                                         ;ndh-005 end
00156              IF(IQBAT.LT.IQLIM .AND.  IFMODE.EQ.0)  GOTO 200
00157    C If not done charging and no mode change requested,
00158    C then repeat charging loop
00159    C End charging loop
00160    C
00161    C
00162              IVLIM=0                    ;Charger OFF
00163              IF(IQBAT.GE.IQLIM)  IFCHG=0 ;CHARGE completed ;ndh-010,020
00164    C
00165              IF(IFEQU.NE.-1 .OR.  IQBAT.LT.IQLIM)  GOTO 600 ;Equ. complete?
00166                IIQ=IFEQU                                     ;mod.5 start
00167                IQX=IQABS
00168                VERR=0.0
00169                VDELQ=0.0                                     ;mod.5 end
00170                IQBAT=0
00171                IQABS=0              ;Reset Absolute Amp-Hours
00172                IEQTIM=0             ;Reset Equilize Timer
00173                IFEQU=0              ;Reset Equilize Flag
00174                IQLAST=0                                      ;ndh-004
```

```
00175             IDSOC=10              ;Reset S-O-C Display ;ndh-005
00176             GOTO 900                                   ;ndh-004
00177    C
00178    600        CONTINUE             ;   NO.
00179    C Update total charge taken from battery since last equilization
00180             IQABS=IQABS-QDIS+IQB4-IQSOC                ;ndh-006
00181    C5 Calculate weighted average voltage prediction error        ;mod.5 sta
00182             VDELQ=VDELQ+QDIS*VDELF
00183             IF(IQABS.EQ.0)IQABS=1
00184             VDELT=-VDELQ/IQABS
00185             VERRT=VERR                                 ;mod.5 end
00186    C Save battery state-of-charge normalized for temperature
00187             IQLAST=IQB4*-62.0/QACC                     ;ndh-003,004,005,020
00188             IQBAT=IQSOC
00189    C
00190    ,00        CONTINUE
00191    C5 Set THINK MODE flag                                    ;mod.5 sta
00192             IFTHK=-1                                   ;mod.5 end
00193    C Grant Mode Change Request
00194             IFMODE=-1
00195    C
00196             RETURN
00197             END
00198    C
00199    C
00200    C ***********************************************************
00201    C
00202    C         TEMPFN
00203    C
00204    C Description:
00205    C Returns the value of a temperature dependant variable of the form.
00206    C
00207    C                 |
00208    C         Plateau +-------------------           ---------------
00209    C                 |                   \         /
00210    C                 |                    \       /
00211    C                 |                     \     /
00212    C                 |                      \   /
00213    C                 |                       \ /
00214    C         Valley  |. . . . . . . . . . . . V
00215    C                 |
00216    C                 |
00217    C                 +-------+-------+-------+-------+-------
00218    C                         7.5     27.5    47.5          degrees C
00219    C
00220    C Inputs:          Temperature, Plateau, Valley of the function
00221    C
00222    C Outputs:          Evaluated function of temperature
00223    C                   between Plateau and Valley
00224    C
00225    C Subprograms called:          (none)
00226    C
00227    C
00228             FUNCTION TEMPFN(ITBAT,PLATOH,VALLEY)       ;ndh-010
00229    $H    TEMPFN
00230    C
00231    C
00232    C Arguments:          ITBAT         = Temperature of battery (C.)
```

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```
00233    C                PLATOH        = Max value of function below 7.5
00234    C                                  or above 47.5 degrees
00235    C                VALLEY        = Minimum value of function
00236    C                                  at 27.5 degrees C.
00237    C
00238    C
00239    C Declarations:
00240    C
00241    C
00242    C
00243    C Main Body:
00244    C
00245           FARG=ITBAT-27.5                                    ;rdh-020
00246           A2=VALLEY+(PLATOH-VALLEY)/20.*ABS(FARG)            ;rdh-020
00247           AMIN1=PLATOH
00248           IF(A2.LT.AMIN1)  AMIN1=A2
00249           TEMPFN=AMIN1                                       ;rdh-010
00250           RETURN
00251           END
```

```
00001    C       DISFOR                  Motorola-6809                   ndh:27-Sep-82
00002    C
00003    C Written by -          Neil D. Herbert                 03-Sep-82
00004    C                  Computer & Software Systems
00005    C                  Gould Electronics Laboratory
00006    C                  Gould, Inc., Rolling Meadows, Ill.
00007    C                  312/640-4472
00008    C
00009    C Modifications:
00010    C
00011    C       Replaced some integer variables with real in COMMON.
00012    C       Corrections from J. Mezera.
00013    C       Added some constants to the COMMON.
00014    C               Neil D. Herbert                 13-Sep-82       ndh-010
00015    C
00016    C       Corrections from J. Mezera.
00017    C               Neil D. Herbert                 16-Sep-82       ndh-011
00018    C
00019    C       Correction for VMIN from J. Mezera.
00020    C               Neil D. Herbert                 17-Sep-82       ndh-012
00021    C
00022    C       J. Mezera changed IRESET flag and added IFCHG flag setting.
00023    C               Neil D. Herbert                 20-Sep-82       ndh-013
00024    C
00025    C       Removed update of IQABS and test for IQDAT limit.
00026    C       Added check for SQRT(neg. arg).
00027    C               Neil D. Herbert                 22-Sep-82       ndh-014
00028    C
00029    C       Allowed pos. or neg. current by operator.
00030    C       Removed unused argument Instantaneous Battery Current
00031    C       from BATMOD.
00032    C       Skip BATMOD for update of IDMILE
00033    C       if filtered power > -30 watts.
00034    C               Neil D. Herbert                 23-Sep-82       ndh-015
00035    C
00036    C       Edited for Motorola 6809
00037    C               Neil D. Herbert                 27-Sep-82       ndh-020
00038    C
00039    C       Added Calls to AVGFOR routine to filter variables
00040    C               John R. Mezera                  7-Oct-82        jrm-022
00041    C
00042    C       Modified Qmeas algorithm to speed up execution
00043    C       by using a larger iteration step size and updating
00044    C       from last calculated value.
00045    C               John R. Mezera                  28-Oct-82       jrm-023
00046    C
00047    C       Changed Qmeas algorithm to save best correction
00048    C       last calculated. Also added setting of wake-up mode
00049    C               John R. Mezerza                 3-Nov-82        jrm-024
00050    C
00051    C
00052    C5      Changes incorporated to accomplish mod 5 parameter adaptor
00053    C5      algorithm.              Robert T. Calvert  6-Mar-84
00054    C5          1) Added five lines of COMMON after line 'COMMON   BCFD,
00055    C5             BCFV,BCFTIM'
00056    C5          2) In the executive program a new timer location,
00057    C5             IDATIM (2 minutes/bit), was added.
00058    C5          3) Added three lines to initialize variables followins
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```
00059    C5             the line 'C   Initialize Variables'.
00060    C5          4) Deleted line 'C      RDEL=VDEL/AMPS'.
00061    C5          5) Added thirty four lines after the line
00062    C5             'C Error record update for use by "think"mode'
00063    C
00064    C        ************************************************************
00065    C                Discharge Monitor          Ver 2.0
00066    C        ************************************************************
00067    C
00068    C Description:
00069    C        Monitors discharging parameters & provides state of charge
00070    C        and miles for display.
00071    C
00072    C Inputs:          Battery Amp-hour meter value.
00073    C                 Battery temperature, current, voltage, power .
00074    C                 Vehicle speed.
00075    C
00076    C Outputs:           % State-Of-Charge and Miles left.
00077    C
00078    C Subprograms called:          ZONE,VEQ,VDROP,BATMOD
00079    C
00080    C
00081    C
00082           SUBROUTINE DISFOR
00083    $H    DISFOR
00084    C
00085    C Arguments:          (none)
00086    C
00087    C Standard Formats:
00088    C
00089    C Declarations:
00090    C
00091    C                                                    ,ndh-010 begin
00092           COMMON              IFMODE,IWAKEF,IVLIM,IFINI
00093           COMMON              IIBAT,IVBAT,ITBAT,ISPEED
00094           COMMON              AMPSF,TEMPF,PWRF,SPDF
00095           COMMON              IQBAT,IQBATX,IQLAST,IQAEC
00096           COMMON              IFRST,IFCHG,IFTHR                ,ndh-020
00097           COMMON              IFEQU,IRESET,ISFCAL
00098           COMMON              IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00099           COMMON              R1(4,3),R2(4,3),R2(3,3)
00100           COMMON              RK1,RK2,RK3,RK4
00101           COMMON              VEQ1,VEQ2,VEQ3,VEQ4
00102           COMMON              BCFQ,BCFV,BCFTIM
00103    C                                                   ,ndh-010 end
00104           COMMON              IDATIM,IIQ,IFEMA        ,mod.5 start
00105           COMMON              M,JD,JL,IVALID
00106           COMMON              DTEMP(2),DRDEL(9)
00107           COMMON              DVBAT(9),DAMPF(9),DQBAT(9)
00108           COMMON              VDELF,VDELQ,VDELT,VEPRT
00109           COMMON              RDEL,THELTA,TEMP,QCOR
00110           COMMON              PWR,AMPS,THELTB,IQX              ,mod.5 end
00111    C
00112    C
00113    C Function Definitions:
00114    C
00115    C Main Body:
00116    C                                                   ,nhd-010 begin
```

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```
00117   C                                                       ;ndh-010 end
00118   C
00119   C Adjust for Self-discharge
00120         IQBAT=IQBAT+IDCTIM*RK1                                  ;ndh-020
00121         IDCTIM=0
00122   C
00123   C Initialize variables
00124         JD=0                                              ;mod. 5 start
00125         IQT=0
00126         VDELS=0.0                                         ;mod. 5 end
00127         THELTA=0.0
00128         QMEAS=IQBAT*BCFQ
00129         QCOR=0.0
00130   C
00131   C Begin Discharging loop    ++++++++++++++++++++++++++++++++++++++++++++++++++
00132   200       CONTINUE
00133   C Run Average Routine if needed
00134         CALL AVGFOR                                       ;Jrm-022
00135   C
00136   C If charge removed >= 500 A.Hr or its been >= 7 days,
00137   C then set equalize flag.
00138         IF((IQABS+IQBAT).LT.-2065 .OR. IEQTIM.GE.5040)
00139   &        IFEQU=-1 ;Time to Equalize?                      ;ndh-010,014,020
00140   C
00141   C Set Wake-up mode for 2 hours if at least 4.8 A-hr have
00142   C been removed since last charge cycle
00143         IF((IQLAST-IQBAT).GT.20) IWAKEF=2                   ;Jrm-024
00144   C
00145   C Determine Battery State                                 ;ndh-010 begin
00146         CALL ZONE(AMPSF,TEMPF,R1E,R2E,Q2E)
00147         TEMP=TEMPF
00148         AMPS=AMPSF
00149         TBAT=ITBAT
00150         QBAT=IQBAT*BCFQ
00151         ABAT=IIBAT*0.1
00152         VBAT=IVBAT*BCFV
00153         VPRED=VEQ(QBAT,TBAT)-VDROP(AMPS,R1E,R2E,Q2E,QBAT,ALAF)  ;ndh-020
00154         VDEL=VBAT-VPRED
00155   C                                                       ;ndh-010 end
00156   C Error record update for use by "think" mode
00157         RDEL=VDEL/AMPS                                    ;mod 5 start
00158   C5 Record discharge data only when battery discharged
00159   C5 over half capacity
00160         IF(QBAT/Q2E.LT.0.5) GO TO 400
00161           IF(IDATIM.LT.2) GO TO 350
00162             IF(JD.NE.0)GO TO 250
00163               DTEMP(1)=TEMPF
00164               JD=1
00165   250          CONTINUE
00166             IF(JD.NE.10) GO TO 270
00167   C5 Index data record to get most recent nine points
00168               DO 260 K=2,9
00169                 DRDEL(K-1)=DRDEL(K)
00170                 DVBAT(K-1)=DVBAT(K)
00171                 DAMPF(K-1)=DAMPF(K)
00172                 DQBAT(K-1)=DQBAT(K)
00173   260            CONTINUE
00174               JD=9
```

```
00175   C5 Record discharge profile data point
00176   270             CONTINUE
00177                 DTEMP(2)=TEMPF
00178                 DRDEL(JD)=RDEL
00179                 DVBAT(JD)=VBAT
00180                 DAMPF(JD)=AMPSF
00181                 DQBAT(JD)=QBAT
00182                 JD=JD+1
00183                 IDATIM=0
00184   C5 Test data point for regeneration
00185   350           CONTINUE
00186               IF(AMPSF.GT.0) GO TO 400
00187   C5 Calculate weighted average of voltage prediction error
00188                 IQT=IQT+IQBAT
00189                 VDELS=VDELS+VDEL*IQBAT
00190                 VDELF=VDELS/IQT
00191   400         CONTINUE                                    ;mod.5 end
00192   C
00193   C Predict Voltage Error & Compensate A.Hr value for battery model
00194           IF(AMPS.GE.-5.0) GOTO 600                       ;rdh-015
00195             IF(VDEL.GT.-20.0E-3)  GOTO 570                ;rdh-012,020,023
00196   C Only correct QBAT if VDEL is more negative than -20mv   ;rdh-012
00197                 FARG=AMPS-ABAT
00198                 GAMMA=2.0/ZRQQ1(1.0,Q2E,QBAT)*ABS(FARG)/5.0
00199                 THELTB=0.7/(1.0+GAMMA)                    ;jrm-024 begin
00200                   IF(THELTB.LT.THELTA-.05) GO TO 560
00201                     THELTA=THELTB                         ;jrm-024 end
00202                 VPRIME=VEQ(QMEAS,TBAT)-VDROP(AMPS,R1E,R2E,Q2E,QMEAS,ABAT)
00203                 STEP=1.0                                  ;rdh-011
00204                 IF(VPRIME.GT.VBAT)  STEP=-1.0
00205   550             CONTINUE
00206                   QMEAS=QMEAS+STEP*2.0                    ;rdh-020,023
00207                   VPRIME=VEQ(QMEAS,TBAT)-VDROP(AMPS,R1E,R2E,Q2E,QMEAS,ABAT)
00208                   IF((VPRIME-VBAT)*STEP.LE.0.0)  GOTO 550
00209                   QMEAS=QMEAS-STEP*2.0                    ;jrm-023
00210                     FARG=THELTA*(QMEAS-QBAT)
00211                     IF(QCOR.LT.FARG) GO TO 555
00212                     QCOR=FARG                             ;jrm-024
00213   555               CONTINUE
00214   560             CONTINUE                                ;jrm-024
00215   570           CONTINUE
00216   600         CONTINUE                                    ;rdh-015
00217           QI=QBAT+QCOR                          ;jrm-024
00218   C
00219   C Calculate State-Of-Charge at "Standard" Rate for Bar Display
00220           PWR=-185.2                                      ;rdh-020
00221           VCUT=1.443                                      ;rdh-020
00222   C                                                       ;rdh-010 test
00223           TIME=BATMOD(AMPS,TEMP,QI,PWR,VCUT)              ;rdh-015
00224           TIME=TIME*9.25              ;10*185w/cell/(200w Hr/cell)
00225           IF(TIME.GT.10.0)  TIME=10.0 ;max display range
00226           IDSOC=TIME+0.5              ;round up integer
00227   C
00228   C Calculate State-Of-Charge at "Driving" Rate for Miles Display
00229           IF(PWRF.GT.-30.0)  GOTO 220                     ;rdh-015
00230   C If filtered power out of battery is less than 30 watts.
00231   C skip BATMOD ;rdh-015
00232             PWR=PWRF
```

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```
00233   C                                                       ;ndh-014 begin
00234           FARG=1.0+2.77E-3*PWR
00235           IF(FARG.LT.0.0)  FARG=0
00236           VCUT=0.85*(1.0+SQRT(FARG))
00237   C                                                       ;ndh-014 end
00238   C          .5*1.70v/cell*(1+SQRT(1-4*.002v/cell/AMP/PWR/1.7**2))
00239   C Run Average Routine if needed
00240           CALL AVGFOR                                     ;jrm-022
00241   C
00242           TIMEM=BATMOD(AMPS,TEMP,QI,PWR,VCUT)             ;ndh-015
00243   220      CONTINUE
00244         IDMILE=SPDF*TIMEM/ISPCAL+0.5 ;(pulses/hour)/(pulses/mile)
00245   C                                                       ;ndh-010 end
00246   C
00247           IF(IFMODE.EQ.0)  GOTO 200
00248   C If not done discharging, then repeat discharging loop ^
00249   C End discharging loop    ==========================================
00250   C
00251   C
00252   C Set Charge Flag if 10A-hr or more removed
00253           IF(IQLAST-IQBAT.LT.-41) IFCHG=-1    ;ndh-013
00254   C
00255   C Grant Mode Change Request
00256           IFMODE=-1
00257   C
00258           RETURN
00259           END
```

```
00001    C        THKFOR                  Motorola-6809
00002    C
00003    C Written by -          Robert T. Calvert              22-Feb-84
00004    C                       Gould Research Center
00005    C                       Gould, Inc., Rolling Meadows, Ill.
00006    C
00007    C Modifications:
00008    C
00009    C        ************************************************************
00010    C                Battery Parameter Adaptor      Ver 2.0
00011    C        ************************************************************
00012    C
00013    C Description:
00014    C        If needed, the battery parameter Q2(4,3) will be
00015    C        changed to compensate for the aging of the battery
00016    C
00017    C Inputs:          Battery discharge profile data collected
00018    C                  in DISFOR and the weighted average voltage
00019    C                  prediction error.
00020    C
00021    C Outputs:         Corrected values of capacity Q2(4,3).
00022    C
00023    C Subprograms called:        DATFOR,EMAFOR,IDAFOR
00024    C
00025    C
00026           SUBROUTINE THKFOR
00027    $H    THKFOR
00028    C
00029    C Arguments:          (none)
00030    C
00031    C Standard Formats:
00032    C
00033    C Declarations:
00034    C
00035           COMMON                  IFMODE,IWAKEF,IVLIM,IFINI
00036           COMMON                  IIBAT,IVBAT,ITBAT,ISPEED
00037           COMMON                  AMPSF,TEMPF,PWRF,SPDF
00038           COMMON                  IQBAT,IQBATX,IQLAST,IQABS
00039           COMMON                  IFRST,IFCHG,IFTHK
00040           COMMON                  IFEQU,IRESET,ISPCAL
00041           COMMON                  IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00042           COMMON                  R1(4,3),R2(4,3),Q2(4,3)
00043           COMMON                  RK1,RK2,RK3,RK4
00044           COMMON                  VEQ1,VEQ2,VEQ3,VEQ4
00045           COMMON                  BCFQ,BCFV,BCFTIM
00046           COMMON                  IDATIM,IIQ,IFEMA
00047           COMMON                  M,JD,JL,IVALID
00048           COMMON                  DTEMP(2),DRDEL(9)
00049           COMMON                  DVBAT(9),DAMPF(9),DQDAT(9)
00050           COMMON                  VDELF,VDELQ,VDELT,VERRT
00051           COMMON                  RDEL,THELTA,TEMP,QCOR
00052           COMMON                  PWR,AMPS,THELTB,IQX
00053    C
00054    C
00055    C Function Definitions:
00056    C
00057    C Main Body:
00058    C
```

```
00059           CALL DATFOR          ;Test discharge data profile for validity
00060           IF(IVALID. EQ. 1) GO TO 200
00061             IF(IIQ. NE. -1) GO TO 700
00062               IF(IFEMA. EQ. 1) GO TO 500
00063                 CALL IDAFOR    ;Incremental default algorithm
00064                 GO TO 700
00065   200         CONTINUE
00066                 CALL EMAFOR(Q2E,Q2EO)     ;Error minimization algorithm
00067                   IF(Q2E. EQ. Q2EO) GO TO 700
00068                     IFEMA=1
00069                     GO TO 700
00070   500             CONTINUE
00071               IFEMA=0
00072   700          CONTINUE
00073   C Reset data collection variables
00074           DTEMP(1)=0. 0
00075           DTEMP(2)=0. 0
00076           IIQ=0
00077           IQX=0
00078           IVALID=0
00079           DO 800 K=1,2
00080             DRDEL(K)=0. 0
00081             DVBAT(K)=0. 0
00082             DAMPF(K)=0. 0
00083             DQBAT(K)=0. 0
00084   800        CONTINUE
00085   C
00086   C Return Control To Executive
00087           IFTHK=0                ,THINK  cycle completed
00088           IFMODE=-1
00089           RETURN
00090           END
```

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```
00001    C       DATFOR
00002    C
00003    C
00004    C Written by -      Robert T. Calvert      22-Feb-84
00005    C                   Gould Research Center
00006    C                   Rollins Meadows, Ill.
00007    C
00008    C
00009    C Modifications:
00010    C
00011    C
00012    C
00013    C
00014    C      ************************************************************
00015    C         Test for Discharge Profile Data Validity      Ver 1.0
00016    C      ************************************************************
00017    C
00018    C Description:
00019    C       Tests discharge data points that were recorded in DISFOR
00020    C       for Constant Power within plus or minus ten percent.
00021    C
00022    C Inputs:     Discharge Profile Data
00023    C
00024    C Outputs:    IVALID flag ; 1=valid, 0=not valid
00025    C
00026    C Subprograms called.      (none)
00027    C
00028    C
00029          SUBROUTINE DATFOR
00030    $H      DATFOR
00031    C
00032    C Arguments:       (none)
00033    C
00034    C Standard Formats:
00035    C
00036    C Declarations:
00037    C
00038          COMMON          IFMODE,IWAKEF,IVLIM,IFINI
00039          COMMON          IIBAT,IVBAT,ITBAT,ISPEED
00040          COMMON          AMPSF,TEMPF,PWRF,SPDF
00041          COMMON          IQBAT,IQBATX,IQLAST,IQABS
00042          COMMON          IFRST,IFCHG,IFTHK
00043          COMMON          IFEQU,IRESET,ISPCAL
00044          COMMON          IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00045          COMMON          R1(4,3),R2(4,3),Q2(4,3)
00046          COMMON          RK1,RK2,RK3,RK4
00047          COMMON          VEQ1,VEQ2,VEQ3,VEQ4
00048          COMMON          BCFQ,BCFV,BCFTIM
00049          COMMON          IDATIM,IIQ,IFEMA
00050          COMMON          M,JD,JL,IVALID
00051          COMMON          DTEMP(2),DRDEL(9)
00052          COMMON          DVBAT(9),DAMPF(9),DQBAT(9)
00053          COMMON          VDELF,VDELQ,VDELT,VERRT
00054          COMMON          RDEL,THELTA,TEMP,QCOR
00055          COMMON          PWR,AMPS,THELTB,IQX
00056    C
00057    C
00058    C Main Body:
```

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```
00059   C
00060           IVALID=0
00061   C Test for at least four data points
00062           JK=JD-1
00063           IF(JK.LT.4.OR.JK.GT.9) GO TO 900
00064   C Is voltage close enough to cutoff?
00065           IF(DVBAT(JD-1).GT.1.77.OR.DVBAT(JD-1).LT.1.2) GO TO 900
00066   C Regeneration test
00067           K=0
00068           GO TO 200
00069   100          CONTINUE
00070           JL=JD-K-1
00071   200          CONTINUE
00072           K=K+1
00073           JK=JD-K
00074           IF(JK.LT.1) GO TO 900
00075           IF(DAMPF(JK).GT.0.0) GO TO 100
00076           JL=JD-K
00077           IF(JL.LT.4) GO TO 900
00078   C Test for four consecutive points with power constant
00079   C within ten percent
00080           GO TO 400
00081   300          CONTINUE
00082           IF(M.LE.4) GO TO 900
00083           JL=M-1
00084   400          CONTINUE
00085           M=JL
00086   500          CONTINUE
00087           IF(M.LT.2.OR.M.GT.9) GO TO 900
00088           PWR=(DAMPF(M)*DVBAT(M)-DAMPF(M-1)*DVBAT(M-1))/
00089   &       (DAMPF(JL)*DVBAT(JL))
00090           IF(ABS(PWR).GT.0.1) GO TO 600
00091           M=M-1
00092           IF(M.NE.1) GO TO 500
00093   600          CONTINUE
00094           IF(JL-M.LT.3) GO TO 300
00095           IF(DAMPF(JL-1).GE.0.0) GO TO 900      ;regeneration test
00096   C Data has passed validity tests
00097           IVALID=1
00098   900          CONTINUE
00099           RETURN
00100           END
```

```
00001    C        IDAFOR
00002    C
00003    C
00004    C Written by --          Robert T. Calvert        22-Feb-84
00005    C                        Gould Research Center
00006    C                        Rolling Meadows, Ill.
00007    C
00008    C
00009    C Modifications:
00010    C
00011    C
00012    C
00013    C
00014    C        ************************************************************
00015    C           Incremental Default Algorithm for Q2 Adaptation   Ver 1.0
00016    C        ************************************************************
00017    C
00018    C Description:
00019    C        Decrement or Increment Q2(4,3) based on
00020    C        Average Voltage Prediction Error.
00021    C
00022    C Inputs:    Average Voltage Prediction Error (dynamic and rest)
00023    C            Absolute Amp Hours since last equalization
00024    C
00025    C Outputs:   Updated Capacity Parameter Q2(4,3)
00026    C
00027    C Subprograms called:     (none)
00028    C
00029    C
00030          SUBROUTINE IDAFOR
00031    $H      IDAFOR
00032    C
00033    C Arguments:      (none)
00034    C
00035    C Standard Formats:
00036    C
00037    C Declarations:
00038    C
00039          COMMON          IFMODE,IWAKEF,IVLIM,IFINI
00040          COMMON          IIBAT,IVBAT,ITBAT,ISPEED
00041          COMMON          AMPSF,TEMPF,PWRF,SPDF
00042          COMMON          IQBAT,IQBATX,IQLAST,IQABS
00043          COMMON          IFRST,IFCHG,IFTHK
00044          COMMON          IFEQU,IRESET,ISPCAL
00045          COMMON          IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM,IDATIM
00046          COMMON          IAHREQ,IEQCH,INORCH
00047          COMMON          R1(4,3),R2(4,3),Q2(4,3)
00048          COMMON          RK1,RK2,RK3,RK4
00049          COMMON          VEQ1,VEQ2,VEQ3,VEQ4
00050          COMMON          BCFQ,BCFV,BCFTIM
00051          COMMON          IIQ,IFEMA
00052          COMMON          M,JD,JL,IVALID
00053          COMMON          DTEMP(2),DRDEL(9)
00054          COMMON          DVBAT(9),DAMPF(9),DQBAT(9)
00055          COMMON          VDELF,VDELQ,VDELT,VERRT
00056          COMMON          RDEL,THELTA,TEMP,QCOR
00057          COMMON          PWR,AMPS,THELTD,IQX
00058    C
```

```
00059    C
00060    C Main Body
00061    C
00062           IF(VDELT. LT. 0. 02. AND. VERRT. LT. 0. 02) GO TO 100
00063            IF(VDELT. GT. 0. 05. AND. VERRT. GT. 0. 05)GO TO 500
00064              GO TO 900
00065    100       QCOR=IQX*BCFQ*(5. 0E-5)          ;Decrement value for Q2
00066                IF(QCOR. GE. (-0. 025)) GO TO 200
00067                  QCOR=-0. 025                   ;Limit decrement to 2. 5%
00068    200            CONTINUE
00069                  DO 400 J=1,4                   ;Distribute change in array
00070                    DO 300 K=1,3
00071                      Q2(J,K)=Q2(J,K)*(1+QCOR)
00072    300               CONTINUE
00073    400             CONTINUE
00074                  GO TO 900
00075    500         CONTINUE
00076                QCOR=IQX*BCFQ*(-2. 0E-5)         ;Increment value for Q2
00077                IF(QCOR. LE. 0. 01) GO TO 200
00078                  QCOR=0. 01                     ;Limit increase of Q2 to 1. 0 %
00079                  GO TO 200
00080    900         CONTINUE
00081           RETURN
00082           END
```

```
00001    C        EMAFOR
00002    C
00003    C
00004    C Written by -          Robert T. Calvert        22-Feb-84
00005    C                       Could Research Center
00006    C                       Rollins Meadows, Ill.
00007    C
00008    C
00009    C Modifications:
00010    C
00011    C
00012    C
00013    C
00014    C        ************************************************************
00015    C           Error Minimization Algorithm for Q2 adaptation     Ver 1.0
00016    C        ************************************************************
00017    C
00018    C Description:
00019    C        Decrement or Increment Q2(4,3) based on Error
00020    C        Minimization using Discharge Profile Data.
00021    C
00022    C Inputs:     Discharge Profile Data collected in DISFOR
00023    C
00024    C Outputs:    Updated Capacity Parameter Q2(4,3), Q2E,
00025    C             and Beginning Q2E
00026    C
00027    C Subprograms called:     VEQ,VDROF,ZONE
00028    C
00029    C
00030          SUBROUTINE EMAFOR(Q2E,Q2E0)
00031    $H      EMAFOR
00032    C
00033    C Arguments:     Q2E      Updated Interpolated Capacity Q2
00034    C                Q2E0     Beginning Interpolated Capacity Q2
00035    C
00036    C Standard Formats:
00037    C
00038    C Declarations:
00039    C
00040          COMMON        IFMODE,IWAKEF,IVLIM,IFINI
00041          COMMON        IIBAT,IVBAT,ITBAT,ISPEED
00042          COMMON        AMPSF,TEMPF,PWRF,SPDF
00043          COMMON        IQBAT,IQBATX,IQLAST,IQABS
00044          COMMON        IFRST,IFCHG,IFTHK
00045          COMMON        IFEQU,IRESET,ISPCAL
00046          COMMON        IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00047          COMMON        R1(4,3),R2(4,3),Q2(4,3)
00048          COMMON        RK1,RK2,RK3,RK4
00049          COMMON        VEQ1,VEQ2,VEQ3,VEQ4
00050          COMMON        BCFQ,BCFV,BCFTIM
00051          COMMON        IDATIM,IIQ,IFEMA
00052          COMMON        M,JD,JL,IVALID
00053          COMMON        DTEMP(2),DRDEL(9)
00054          COMMON        DVBAT(9),DAMPF(9),DQBAT(9)
00055          COMMON        VDELF,VDELQ,VDELT,VERRT
00056          COMMON        RDEL,THELTA,TEMP,QCOR
00057          COMMON        PWR,AMPS,THELTB,IQX
00058    C
```

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```
00059   C
00060   C Main Body:
00061   C
00062   C
00063   C Calculate averase battery temperature
00064           TEMP=0.5*(DTEMP(2)+DTEMP(1))
00065           PWR=(DTEMP(2)-DTEMP(1))/DTEMP(1)
00066           IF(ABS(PWR).GT.0.25) GO TO 900
00067           QCOR=DQBAT(JL)-DQBAT(M)
00068   C Calculate averase current
00069           AMPS=0.0
00070           J=M
00071           GO TO 120
00072   100          CONTINUE
00073           J=J+1
00074   120          CONTINUE
00075           QI=DQBAT(J+1)-DQBAT(J)
00076           AMPS=AMPS+(DAMPF(J+1)+DAMPF(J))*QI
00077           IF(J.NE.(JL-1)) GO TO 100
00078           AMPS=AMPS/(2*QCOR)
00079   C Get interpolated values of battery parameters
00080           CALL ZONE(AMPS,TEMP,R1E,R2E,Q2E)
00081   C Calculate averase error in impedance prediction
00082           RDEL=0.0
00083           J=M
00084           GO TO 140
00085   130          CONTINUE
00086           J=J+1
00087   140          CONTINUE
00088           QI=DQBAT(J+1)-DQBAT(J)
00089           RDEL=RDEL+(DRDEL(J+1)+DRDEL(J))*QI
00090           IF(J.NE.(JL-1)) GO TO 130
00091           RDEL=RDEL/(2*QCOR)
00092   C Initialization for error comparison routines
00093           THELTA=1000.0
00094           N=0
00095           Q2EO=Q2E
00096   150          CONTINUE
00097   C Calculate integral squared error in impedance prediction
00098           THELTB=0.0
00099           J=M
00100           GO TO 170
00101   160          CONTINUE
00102           J=J+1
00103   170          CONTINUE
00104           QI=DQBAT(J+1)-DQBAT(J)
00105           THELTB=THELTB+((DRDEL(J+1)+DRDEL(J))**2)*QI
00106           IF(J.NE.(JL-1)) GO TO 160
00107           THELTB=ABS(THELTB)
00108           IF((RDEL*AMPS).GT.0.02) GO TO 500
00109           IF(THELTB.GE.THELTA) GO TO 400
00110           IF(N.EQ.5) GO TO 800                    ;Limit total decrease to 5%
00111   C Try decreasing Q2E by one percent
00112           Q2E=Q2E*0.99
00113   200          CONTINUE
00114           K=M
00115   250          CONTINUE
00116   C Calculate new impedance prediction error
```

```
00117            VPRED=VEQ(DQBAT(K),TEMP)-VDROP*(DAMPF(K),R1E,R2E,
00118     &        Q2E,DQBAT(K),DAMPF(K))
00119            VDEL=DVBAT(K)-VPRED
00120            DRDEL(K)=VDEL/DAMPF(K)
00121            K=K+1
00122            IF(K.LE.JL) GO TO 250
00123            THELTA=THELTB
00124            N=N+1
00125            GO TO 150
00126     400          CONTINUE
00127     C Final adjustment of Q2E
00128            Q2E=Q2E*1.01
00129            GO TO 800
00130     500          CONTINUE
00131            IF(RDEL*AMPS.LT.0.05) GO TO 900
00132            IF(THELTB.GE.THELTA) GO TO 700
00133            IF(N.EQ.5) GO TO 800
00134     C Try increasing Q2E by one percent
00135            Q2E=Q2E*1.01
00136            GO TO 200
00137     700          CONTINUE
00138     C Final adjustment of Q2E
00139            Q2E=Q2E*0.99
00140     800          CONTINUE
00141     C Distribute Q2E change in Q2 array
00142            DO 840 J=1,4
00143              DO 820 K=1,3
00144                Q2(J,K)=Q2(J,K)*(Q2E/Q2E0)
00145     820          CONTINUE
00146     840        CONTINUE
00147     900          CONTINUE
00148            RETURN
00149            END
```

```
00001   C       BATMOD                          Motorola-6809       ndh:27-Sep-82
00002   C
00003   C Written by -          Neil D. Herbert                 09-Sep-82
00004   C                   GLEER Computer & Software Systems
00005   C                   Gould, Inc., Rolling Meadows, Ill.
00006   C                   312/640-4472
00007   C
00008   C Modifications:
00009   C       Changed integer arguments to real.
00010   C       Changed from Subroutine to Function.
00011   C       Corrections from J. Mezera.
00012   C               Neil D. Herbert             13-Sep-82       ndh-010
00013   C
00014   C       Corrections from J. Mezera.
00015   C               Neil D. Herbert             16-Sep-82       ndh-011
00016   C
00017   C       Change from J. Mezera which by-passes ZONE to speed up
00018   C       algrithm if current hasn't changed by more than 1Amp
00019   C               Neil D. Herbert             17-Sep-82       ndh-012
00020   C
00021   C       Changed test for skip ZONE to avoid divide-by-zero error.
00022   C               Neil D. Herbert             22-Sep-82       ndh-013
00023   C
00024   C       Removed argument Instantaneous Battery Current ABAT0.
00025   C       Added Return if time to Cutoff Volatse exceeds 12 hours
00026   C               Neil D. Herbert             23-Sep-82       ndh-014
00027   C
00028   C       Edited for Motorola-6809.
00029   C               Neil D. Herbert             27-Sep-82       ndh-020
00030   C
00031   C       Added two step simulation rate depending upon discharge rate
00032   C       or when simulation nears knee of voltage profile. This decreased
00033   C       exection time with minimal degradation in simulation accuracy.
00034   C               John R. Mezera               7-Oct-82       jrm-021
00035   C
00036   C       ********************************************************
00037   C               Battery Model          Ver 2.0
00038   C       ********************************************************
00039   C
00040   C Description:
00041   C       Models the battery in increments of time
00042   C       using the input parameters as a starting point.
00043   C       and iteratively removes energy at constant power
00044   C       until the cutoff voltage is reached.
00045   C
00046   C Inputs:       Battery current, temperature, state, power,
00047   C               & cutoff voltage
00048   C                                                   ;ndh-010 begin
00049   C Outputs:       Hours to cutoff voltage
00050   C
00051   C Subprograms called:       ZONE,VEQ,VDROP
00052   C
00053   C
00054   C
00055         FUNCTION BATMOD(AMPS0,TEMP0,QI,PWR,VCUT)
00056   $H    BATMOD
00057   C
00058   C Arguments:                                           ;ndh-014
```

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```
00059   C                AMPS0       = Battery Current filtered over 6 min.
00060   C                TEMP0       = Battery Temperature filtered over 6 min.
00061   C                QI        = Modified State of charge
00062   C                PWR        = Power Rate filtered over 30 sec
00063   C                VCUT        = Cutoff Voltage
00064   C
00065   C Standard Formats:
00066   C
00067   C Declarations:
00068   C
00069   C                                ORIGINAL PAGE IS
00070   C                                OF POOR QUALITY       ;ndh-020
00071   C
00072   C Main Body:
00073   C
00074           AMPS=AMPS0
00075           ABAT=AMPS0                                      ;ndh-014
00076           Q=QI
00077           TIME=0.0
00078   C
00079   C  Beginning of Iteration Loop   ++++++++++++++++++++++++++++++++++++
00080   200        CONTINUE
00081   C Predict Battery Voltage
00082           CALL ZONE(AMPS,TEMP0,R1E,R2E,Q2E)              ;ndh-011
00083           AMPZ=AMPS     ;last current used in ZONE ;ndh-012
00084   C
00085   C Inner loop to skip ZONE    ++++++++++++++++++++
00086   300           CONTINUE                                  ;ndh-012
00087             VPRED=VEQ(Q,TEMP0)-VDROP(AMPS,R1E,R2E,Q2E,Q,ABAT) ;ndh-011
00088   C
00089             BATMOD=TIME
00090             IF(VPRED.LE.VCUT) RETURN     ;ndh-014,Jrm-021
00091             IF(TIME.GT.12.0) RETURN      ;Jrm-021
00092   C
00093   C Re-Compute Battery Current
00094             ABAT=PWR/VPRED
00095   C
00096   C Two step simulation
00097   C      Fast rate if dischrage rate low (<75watts/cell)
00098   C      Slow rate at knee of characteristic (within 80% of Q2E)
00099   C
00100             IF(PWR.GT.-75.0) GO TO 400    ;Jrm-021
00101             IF(Q.GT.Q2E*0.80) GO TO 400    ;Jrm-021
00102   C      Slow Rate:    18 sec simulation
00103             AMPS=AMPS*0.952+ABAT*0.048 ;A/(1+t/T)+a/(1+T/t) ;ndh-020
00104   C Increment Time
00105             Q=Q+ABAT*.005 ;model hours "t"     ;ndh-020
00106             TIME=TIME+.005 ;t                   ;ndh-020
00107             GO TO 500
00108   C      Fast Rate.    4 min simulation
00109   400 CONTINUE
00110             AMPS=AMPS*0.600+ABAT*0.400 ;A/(1++t/T)+a/(1+T/t) ;Jrm-021
00111   C Increment Time
00112             Q=Q+ABAT*.0667 ;model hours "t"     ;Jrm-021
00113             TIME=TIME+.0667 ;t                  ;Jrm-021
00114   500 CONTINUE
00115   C
00116             FARC=AMPS-AMPZ                      ;ndh-020
```

```
00117              IF(ABS(FARG).LT.1.0)  GOTO 300     ;ndh-012,013,014,020
00118     C If current hasn't changed by more than 1Amp,
00119     C then skip ZONE ;ndh-012,013
00120     C                                                    ;ndh-010 end
00121           GOTO 200
00122     C End of Iteration Loop     ==========================================
00123     C
00124     C
00125           END
```

```
00001          SUBROUTINE AVGFOR
00002     *
00003     $H         AVGFOR
00004          COMMON IFMODE,IWAKEF,IVLIM,IFINT
00005          COMMON IIBAT,IVBAT,ITBAT,ISPEED
00006          COMMON AMPSF,TEMPF,PWRF,SPDF              ;REAL DATA TYPE
00007          COMMON IQBAT,IQBATX,IQLAST,IQABS
00008          COMMON IFRST,IFCHG,ITHK
00009          COMMON IFEQU,IRESET,ISPCAL
00010          COMMON IDSOC,IDMILE,IDCTIM,IEQTIM,ICQTIM
00011          COMMON R1(4,3),R2(4,3),Q2(4,3)
00012          COMMON RK1,RK2,RK3,RK4
00013          COMMON VEQ1,VEQ2,VEQ3,VEQ4
00014          COMMON BCFQ,BCFV,BCFTIM
00015          COMMON IDATIM,IIQ,IFEMA                   ;mod 5 start
00016          COMMON M,JD,JL,IVALID
00017          COMMON DTEMP(2),DRDEL(9)
00018          COMMON DVBAT(9),DAMPF(9),DQBAT(9)
00019          COMMON VDELF,VDELQ,VDELT,VERRT
00020          COMMON RDEL,THELTA,TEMP,QCOR
00021          COMMON PWR,AMPS,THELTB,IQX                ;mod 5 end
00022     *
00023     *    TEST FOR INITIALIZATION
00024     *
00025               IF (IFINT.GE.0)  GO TO 100
00026                  TEMPF=ITBAT                      ;INITIALIZE TO REAL VALUE
00027                  IFINT=0                          ;RESET REQUEST FLAG
00028     100       CONTINUE
00029     *
00030     *    CHECK FOR FILTER DELAY
00031     *
00032               IF (IFINT.LT.75) GO TO 200          ;DELAY 10 SEC
00033                  IFINT=0
00034     *
00035     *      AVERAGE CURRENT AND TEMPERATURE OVER A BATTERY TIME CONSTANT (6 M
00036     *
00037               AMPSF=(0.973*AMPSF)+(0.0027*IIBAT)    ;SCALE & AVERAGE TO AMPS (0.
00038     *
00039               TEMPF=(0.973*TEMPF)+(0.027*ITBAT)     ;AVERAGE TO DEGREES (1 C/BIT
00040     *
00041     *     AVERAGE POWER AND SPEED OVER 30 SEC.  TIME INTERVAL
00042     *
00043               PWRF=(.750*PWRF)+(2.315E-5*IIBAT*IVBAT);SCALE & AVERAGE TO WATTS.
00044     *                                                   (0.1A/BIT*.926E-3V/CELL/
00045     *
00046               SPDF=(.750*SPDF)+(150.0*ISPEED)        ;SCALE & AVERAGE TO PULSES/
00047     *                                                   (PULSES / 6 SEC.)
00048     *
00049     200       CONTINUE
00050               RETURN
```

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```
00001    C       VDROP                   Motorola-6809                   ndh:27-Sep-82
00002    C
00003    C Written by -          Neil D. Herbert                 08-Sep-82
00004    C                  GLEER Computer & Software Systems
00005    C                  Gould, Inc., Rolling Meadows, Ill.
00006    C                  312/640-4472
00007    C
00008    C Modifications:
00009    C       Corrections from J. Mezera.
00010    C              Neil D. Herbert                  13-Sep-82        ndh-010
00011    C       Correction in value of R0 from J. Mezera
00012    C              Neil D. Herbert                  16-Sep-82        ndh-011
00013    C
00014    C       Edited for Motorola-6809.
00015    C              Neil D. Herbert                  27-Sep-82        ndh-020
00016    C
00017    C       ************************************************************
00018    C              Voltage Drop        Ver 2.0
00019    C       ************************************************************
00020    C
00021    C Description:
00022    C       Calculates voltage drop for given internal resistance,
00023    C       state of charge, and current values.
00024    C
00025    C Inputs:        Internal battery resistance, charge, and current.
00026    C
00027    C Outputs:         Calculated Voltage drop.
00028    C
00029    C Subprograms called:        ZRQQ1
00030    C
00031    C
00032    C
00033          FUNCTION VDROP(AMPS,R1,R2,Q2,Q,ABAT)
00034    $H    VDROP
00035    C
00036    C Arguments:         AMPS        = Filtered Current
00037    C                R1          = Internal resistance "R1"
00038    C                R2          = Internal resistance "R2"
00039    C                Q2          = Battery capacity
00040    C                Q         = Battery state of charge
00041    C                ABAT        = Instantaneous Current
00042    C
00043    C
00044    C Declarations:
00045    C
00046    C
00047    C                                                       ; ndh-020
00048    C
00049    C Main Body:
00050    C
00051          VDROP=(0.75E-3*R1+ZRQQ1(R2,Q2,Q))*AMPS+0.75E-3*ABAT ; ndh-010,020
00052          RETURN
00053          END
```

```
00001   C       ZONE                    Motorola-6809                   ndh:27-Sep-82
00002   C
00003   C Written by -          Neil D. Herbert                 08-Sep-82
00004   C                   GLEER Computer & Software Systems
00005   C                   Gould, Inc., Rolling Meadows, Ill.
00006   C                   312/640-4472
00007   C
00008   C Modifications:
00009   C
00010   C       Replaced some integer variables with real in COMMON.
00011   C       Corrections from J. Mezera.
00012   C       Added some constants to the COMMON.
00013   C               Neil D. Herbert                 13-Sep-82       ndh-010
00014   C
00015   C       Edited for Motorola 6809.
00016   C               Neil D. Herbert                 27-Sep-82       ndh-020
00017   C
00018   C       ************************************************************
00019   C               Zone Interpolation in 2-D       Ver 2.0
00020   C       ************************************************************
00021   C
00022   C Description:
00023   C       Controls the table search and interpolation for R1, R2, & Q2
00024   C       as functions of current and temperature.
00025   C
00026   C Inputs:       Battery current and temperature.
00027   C
00028   C Outputs:      Interpolated values for R1, R2, & Q2.
00029   C
00030   C Subprograms called:       FDELTA,EVAL2D
00031   C
00032   C
00033   C
00034           SUBROUTINE ZONE(AMPS,TEMP,R1E,R2E,Q2E)
00035   $H    ZONE
00036   C
00037   C Arguments:        AMPS        = Battery current               ;ndh-010
00038   C                   TEMP        = Battery temperature           ;ndh-010
00039   C                   R1E         = Interpolated value of R1
00040   C                   R2E         = Interpolated value of R2
00041   C                   Q2E         = Interpolated value of Q2
00042   C
00043   C Standard Formats:
00044   C
00045   C Declarations:
00046   C
00047   C                                                       ;ndh-010 begin
00048           COMMON              IFMODE,IWAKEF,IVLIM,IFINI
00049           COMMON              IIBAT,IVBAT,ITBAT,ISPEED
00050           COMMON              AMPSF,TEMPF,PWRF,SPDF
00051           COMMON              IQBAT,IQBATX,IQLAST,IQABS
00052           COMMON              IFRST,IFCHG,IFTHK               ;ndh-020
00053           COMMON              IFEQU,IRESET,ISPCAL
00054           COMMON              IDSOC,IDMILE,IDCTIM,IEQTIM,ICGTIM
00055           COMMON              R1(4,3),R2(4,3),Q2(4,3)
00056           COMMON              RK1,RK2,RK3,RK4
00057           COMMON              VEQ1,VEQ2,VEQ3,VEQ4
00058           COMMON              BCFQ,BCFV,BCFTIM
```

```
00059   C                                                          ;ndh-010 end
00060           COMMON              IDATIM,IIQ,IFEMA                ;mod 5 start
00061           COMMON              M,JD,JL,IVALID
00062           COMMON              DTEMP(2),DRDEL(9)
00063           COMMON              DVBAT(9),DAMPF(9),DQBAT(9)
00064           COMMON              VDELF,VDELQ,VDELT,VERRT
00065           COMMON              RDEL,THELTA,TEMP,QCOR
00066           COMMON              PWR,AMPS,THELTB,IQX             ;mod 5 end
00067   C
00068           DIMENSION       LISTA(4),LISTT(3)
00069           DIMENSION       FRACT(2,2)
00070   C
00071   C                                                          ;ndh-020 begin
00072   C                                                          ;ndh-010 begin
00073           LISTA(1)=-20
00074           LISTA(2)=-80
00075           LISTA(3)=-130
00076           LISTA(4)=-200
00077   C                                                          ;ndh-010 end
00078           LISTT(1)=9
00079           LISTT(2)=20
00080           LISTT(3)=40
00081   C                                                          ;ndh-020 end
00082   C
00083   C Main Body:
00084           IAMPS=AMPS                                          ;ndh-010
00085           ITEMP=TEMP                                          ;ndh-010
00086   C
00087   C Determine where we are in the table
00088           J=1
00089           DO 120  I=2,3
00090             IF(IAMPS.LE.LISTA(I))  J=I                        ;ndh-020
00091   120          CONTINUE
00092           K=1
00093           DO 140  I=2,2
00094             IF(ITEMP.GE.LISTT(I))  K=I
00095   140          CONTINUE
00096   C
00097   C Interpolate Values within table
00098           ADEL=FDELTA(IAMPS,LISTA(J),LISTA(J+1))
00099           TDEL=FDELTA(ITEMP,LISTT(K),LISTT(K+1))
00100           FRACT(1,1)=(1-ADEL)*(1-TDEL)
00101           FRACT(1,2)=(1-ADEL)*TDEL
00102           FRACT(2,1)=ADEL*(1-TDEL)
00103           FRACT(2,2)=ADEL*TDEL
00104           R1E=EVAL2D(FRACT,R1,J,K)
00105           R2E=EVAL2D(FRACT,R2,J,K)
00106           Q2E=EVAL2D(FRACT,Q2,J,K)
00107           RETURN
00108           END
```

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```
PAGE 001  FDELTA  . SA:1

00001    C       FDELTA                  Motorola-6809                  ndh: 27-Sep-82
00002    C
00003    C Written by -        .Neil D. Herbert                  08-Sep-82
00004    C                GLEER Computer & Software Systems
00005    C                Gould, Inc., Rollins Meadows, Ill.
00006    C                312/640-4472
00007    C
00008    C Modifications:
00009    C       Corrections from J. Mezera.
00010    C                Neil D. Herberter-82        ndh-010
00011    C
00012    C       Edited for Motorola-6809.
00013    C                Neil D. Herberter-82        ndh-020
00014    C
00015    C       ************************************************************
00016    C                FDELTA value between list points        Ver 2.0
00017    C       ************************************************************
00018    C
00019    C Description:
00020    C       Calculate the fraction of distance that the given value is
00021    C       from the given point in the list to the next point.
00022    C
00023    C Inputs:        Value used in search, the list to search,
00024    C                & the list index.
00025    C
00026    C Outputs:        The fraction of the distance from T(i) to T(i+1).
00027    C
00028    C Subprograms called:        (none)
00029    C
00030    C
00031    C
00032          FUNCTION FDELTA(IPARAM,L1,L2)
00033    $H   FDELTA
00034    C
00035    C Arguments:        IPARAM        = Value used in search
00036    C                L1        = Lower array element of list
00037    C                L2        = Upper array element of list
00038    C
00039    C
00040    C Declarations
00041    C
00042    C
00043    C
00044    C Main Body.
00045    C
00046          FDELTA=(1.0*IPARAM-L1)/(L2-L1)
00047          RETURN
00048          END
```

```
00001    0010 /*        CHGMPL :
00002    0020          CHARGER CONTROL SUBROUTINE CALLED BY BC/SCI EXECUTIVE
00003    0030          THIS PROGRAM CONTROLS THE POWER STAGE BY INCREMENTING
00004    0040          OR DECREMENTING THE CONTROL SET POINT CCOUT AS REQUIRED.
00005    0050           CCOUT : BIT7=ENABLE ; BIT0-6=MAGNITUDE
00006    0060
00007    0070          THE REGULATING ALGORITHM FOLLOWS A CONSTANT POWER PROFILE
00008    0080          REGULATING TO ILIM (ILINE MAX) DEPENDENT UPON FRONT PANEL SI
00009    0090          CHARGING UP TO THE VLIM SET BY THE CHARGE MONITOR ALGORITHM.
00010    0100          THE CONTROL ALGORITHM WILL THEN REGULATE AT THIS VOLTAGE
00011    0110          SETPOINT UNTIL THE CHARGE MONITOR ALGORITHM DETERMINES
00012    0120          THAT THE CHARGE CYCLE IS FINISHED.  (BY SETTING VLIM=0)
00013    0130
00014    0140          POWER STAGE STATUS MAYBE VERIFIED BY CHECKING FCHG (1=ON ; 0=
00015    0150
00016    0160          STATUS INDICATORS ( "CHARGE" & "EQUALIZE" )  ARE CONTROLLED
00017    0170          APPROPRIATE DURING THE CHARGE CYCLE.
00018    0180          "CHARGE" - WILL FLASH DURING POWER ON DELAY
00019    0190                   - STEADY WHEN POWER STAGE ENABLED
00020    0200          "EQUALIZE" -  REQUESTED ONLY BY ALGORITHM BUT MAYBE DEFERED
00021    0210                        (OR TOGGLED) BY DEPRESSING SW2
00022    0220
00023    0230          THIS ROUTINE ALSO PROVIDES POWER STAGE PROTECTION FOR THE FO
00024    0240          ABNORMAL CONDITIONS:
00025    0250                 LOW  BATTERY VOLTAGE - LIMIT MAX CURRENT
00026    0260                 HIGH BATTERY VOLTAGE - INHIBIT CHARGER OPERATION
00027    0270                 TIME LIMIT - FOR OPERATION AT BELOW NORMAL VOLTAGE LI
00028    0280                 TIME LIMIT - TO VOLTAGE REGULATION POINT
00029    0290
00030    0300          VERSION  1.0   28-JUNE-82   JOHN R MEZERA
00031    0310              FILE: CHGMPL4   11/6/82
00032    0320 */
00033    0330
00034    0340 $        NAM    CHGMPL
00035    0350
00036    0360 CHGMPL:   PROCEDURE
00037    0370             GO TO CHGM1       ! SKIP AROUND CONSTANT TABLE
00038    0380
00039    0390
00040    0400
00041    0410 /*
00042    0420          SCALING FACTORS:
00043    0430                 BATTERY  VOLTAGE - 50 MV / BIT
00044    0440                 AC LINE  CURRENT - .01 AMP / BIT
00045    0450                 FAULT TIMER      - 2 MIN / BIT
00046    0460
00047    0470          CONSTANTS:
00048    0480
00049    0490            UNLESS OTHERWISE SPECIFIED ALL VOLTAGES REFER TO BATTERY
00050    0500            AND ALL CURRENTS REFER TO AC LINE CURRENTS
00051    0510
00052    0520              VHYS  -   VOLTAGE HYSTERSIS FOR REGULATION SETPOINT
00053    0530              VHYS2 -   VOLTAGE HYSTERSIS FOR FAULT TIMER
00054    0540              IHYS  -   CURRENT HYSTERSIS FOR REGULATION SETPOINT
00055    0550              ILOW  -   REDUCED LINE CURRENT SETPOINT FOR LOW BATTERI
00056    0560              VMIN  -   MINIMUM VOLTAGE POWER STAGE WILL CHARGE
00057    0570              VMAX  -   MAXIMUM VOLTAGE BEFORE FAULT DISABLE
00058    0580              VLOW  -   ABNORMALLY LOW VOLTAGE WHERE CHARGE CURRENT I
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```
00059   0590
00060   0600            FTIM1 -   FAULT TIME FOR LOW VOLTAGE OPERATION
00061   0610            FTIM2 -   FAULT TIME BEFORE VOLTAGE REGULATION POINT
00062   0620 */
00063   0630
00064   0640        DCL PSCT VHYS  SIGNED BIN(2) INIT(5)     ! .25 V / .050V/BIT
00065   0650        DCL PSCT VHYS2 SIGNED BIN(2) INIT(100)   ! 5 V / .050V/BIT
00066   0660        DCL PSCT IHYS  SIGNED BIN(2) INIT(5)     ! .05 AMPS / .01A/BI
00067   0670        DCL PSCT ILOW  SIGNED BIN(2) INIT(200)   ! 2 AMPS / .01A/BIT
00068   0680        DCL PSCT VMIN  SIGNED BIN(2) INIT(1800)  ! 90 VOLTS / 050V/B
00069   0685 /*     Temp. changed  from normal       (300)   ! 40 VOLTS / .050V/B
00070   0690        DCL PSCT VMAX  SIGNED BIN(2) INIT(3100)  ! 155 VOLTS / .050V.
00071   0700        DCL PSCT VLOW  SIGNED BIN(2) INIT(1800)  ! 90 VOLTS / .050V/B
00072   0710        DCL PSCT FTIM1        BIN(2) INIT(15)    ! 30 MIN / 2MIN/BIT
00073   0720        DCL PSCT FTIM2        BIN(2) INIT(600)   ! 20 HOURS / 2MIN/B
00074   0730
00075   0740
00076   0750
00077   0760 /*     COMPILE TIME CONSTANTS:
00078   0770
00079   0780              ERRBLO   -   BATTERY BELOW MIN VALUE
00080   0790              ERRBHI   -   BATTERY ABOVE MAX VALUE
00081   0800              ERRBOP   -   BATTERY DISCONNECTED DURING OPERATION (
00082   0810              ERRTF1   -   TIME FAULT #1 - FOR LOW VOLTAGE OPERATI
00083   0820              ERRTF2   -   TIME FAULT #2 - BEFORE VOLTAGE REGULATI
00084   0830              ERRSW3   -   INVALID SWITCH SETTING FOR CHARGER OPER
00085   0840              ERRCHG   -   POWER STAGE FAULT
00086   0850 */
00087   0860
00088   0870 /*         FAULT ERROR CODES APPEAR ON DISPLAY AS  0-X OR 2-X
00089   0880
00090   0890        DCL    ERRBLO   CONST($01)
00091   0900        DCL    ERRBHI   CONST($02)
00092   0910        DCL    ERRBOP   CONST($03)
00093   0920        DCL    ERRTF1   CONST($04)
00094   0930        DCL    ERRTF2   CONST($05)
00095   0940        DCL    ERRSW3   CONST($06)
00096   0950
00097   0960        DCL    ERRCHG   CONST($21)
00098   0970
00099   0980
00100   0990
00101   1000 /*
00102   1010        VARIABLES
00103   1020             ILINE  - AC LINE CURRENT
00104   1030             CCOUT  - CHARGER CONTROL OUTPUT SETPOINT NORMAL CONTRO
00105   1040                      $80 -> $FF ; B7=ENABLE  B6-B0 - MAGNITUDE
00106   1050             DCOUNT - INTERNAL DELAY COUNTER FOR SETPOINT UPDATE
00107   1060             ILIM   - CURRENT REGULATION LIMIT
00108   1070             FPIN   - FRONT PANEL SWITCH INPUTS (1ST BYTE DATA INFO
00109   1080             SYIN   - SYSTEM INPUTS (BIT6 = POWER STAGE FAULT)
00110   1090             PTR    - TABLE LOOK-UP POINTER
00111   1100 */
00112   1110
00113   1120
00114   1130        DCL  DSCT  ILINE  SIGNED BIN(2) EXTERNAL ! FORTRAN & EXECUT
00115   1140        DCL  BSCT  CCOUT  SIGNED BIN(1) EXTERNAL
00116   1150        DCL  BSCT  DCOUNT        BIN(1)
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00117   1160        DCL  DSCT  ILIM   SIGNED BIN(2)
00118   1170        DCL  BSCT  FPIN          BIN(1) EXTERNAL ! EXEC. ONLY UPPER
00119   1180        DCL  BSCT  SYIN          BIN(1) EXTERNAL ! EXECUTIVE
00120   1190        DCL  BSCT  PTR           BIN(2)
00121   1200
00122   1210
00123   1220
00124   1230 /*
00125   1240        FLAGS:          MODE FLAG.
00126   1250            FCHGL  - CHARGE LIGHT (INDICATOR FLAG)
00127   1260                     0 ="OFF";    1="ON" ;  -1=FLASH
00128   1270            FPWR   - FULL POWER FLAG SET IF POWER STAGE HAS
00129   1280                     BEEN FULLY ENABLED DURING PRESENT CHARGE CYCLE
00130   1290            FPWR2  - POWER STAGE IS OR WAS ENABLED
00131   1300            FCHGS  - CHARGER STATUS FLAG 1="ON"; 0="OFF"
00132   1310            FFLT   - FAULT FLAG ERROR CODES
00133   1320 */
00134   1330
00135   1340        DCL  BSCT   FCHGL  SIGNED BIN(1)  EXTERNAL
00136   1350        DCL  BSCT   FPWR          BIN(1)
00137   1360        DCL  BSCT   FPWR2         BIN(1)            !EXECUTIVE
00138   1370        DCL  BSCT   FCHGS  SIGNED BIN(1)
00139   1380        DCL  BSCT   FFLT          BIN(1)  EXTERNAL
00140   1390
00141   1400
00142   1410
00143   1420 /*
00144   1430        COMMON SECTION WITH FORTRAN AND EXECUTIVE MODULES
00145   1440          BLANK COMMON VARIABLES:
00146   1450            FMODE  - MODE FLAG  0 = NORMAL; 1 = EXECUTIVE REQUEST C
00147   1460                     -1 = FORTRAN GRANTS CHANGE
00148   1470            WAKEF  - WAKE UP FLAG   BCD  (DAYS; HOURS)
00149   1480            VLIM   - VOLTAGE REGULATION LIMIT
00150   1490
00151   1500            XXXX   - 4 BYTES NOT USED BY CHGMPL
00152   1510
00153   1520            VBAT   - BATTERY VOLTAGE
00154   1530
00155   1540            XXXX   - 34 BYTES NOT USED BY CHGMPL
00156   1550
00157   1560            FEQU   - EQUALIZE FLAG   0=NO;  -1=YES;  SET INITIALLY
00158   1570                     BY  CHARGE MONITOR ALGORITHM
00159   1580            FREQ+1 - LOWER BYTE OF FEQU SET (FF) OR RESET (0) DEPEN
00160   1590                     UPON FRONT PANEL DEFER SWITCH (SW2)
00161   1600
00162   1610            XXXX   - 12 BYTES NOT USED BY CHGMPL
00163   1620
00164   1630            CHGTIM - CHARGE CYCLE TIMER
00165   1640 */
00166   1650
00167   1660
00168   1670        DCL  CSCT   FMODE  SIGNED BIN(2)          ! FORTRAN & EXEC
00169   1680        DCL  CSCT   WAKEF         BIN(2)
00170   1690        DCL  CSCT   VLIM   SIGNED BIN(2)          ! FORTRAN & EXEC
00171   1700 $           CSCT
00172   1710 $           RMB    4
00173   1720        DCL  CSCT   VBAT   SIGNED BIN(2)          ! FORTRAN & EXEC
00174   1730 $           CSCT
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00175   1740 $          RMB     34
00176   1750       DCL  CSCT    FEQU   SIGNED BIN(2)          ! EXECUTIVE
00177   1760 $          CSCT
00178   1770 $          RMB     12
00179   1780       DCL  CSCT    CHGTIM         BIN(2)
00180   1790       .
00181   1800
00182   1810
00183   1820 /*     TABLE  LOOK-UP  MAX  LINE  CURRENT  XX.XX AMPS RMS  */
00184   1830
00185   1840       DCL  PSCT    TBLAMP(1,4) SIGNED BIN(2) INIT(300,600,900,0)
00186   1850       DCL          DATA        SIGNED BIN(2) BASED
00187   1860
00188   1870
00189   1880
00190   1890 CHGM1:
00191   1900 /*   TEST FOR PROPER STATUS BEFORE ENABLING OPERATION
00192   1910      DISABLE IF MODE CHANGING OR SETPOINT NOT YET VALID  */
00193   1920
00194   1930        IF  (FMODE # 0) OR (VLIM < 2160) THEN !CHANGING OR INVALID?
00195   1940          DO                              ! YES
00196   1950            WAKEF = $0700                 ! SET 7 DAY WAKE-UP TIME
00197   1960            FPWR  = 0                     ! INITIALIZE FLAGS
00198   1970            CHGTIM= 0                     ! INITIALIZE / RESET TIMER
00199   1980            GO TO CHGOFF                  ! DISABLE POWER STAGE AND RETURN
00200   1990          END
00201   2000
00202   2010
00203   2020
00204   2030 /*   TEST FOR POWER STAGE FAULT   NOTE: FAULT BIT (SYIN BIT6)
00205   2040           1=FAULT - IF POWER STAGE NEVER ENABLED
00206   2050           0=FAULT - ONCE POWER STAGE ENABLED              */
00207   2060
00208   2070 $  LDA    SYIN
00209   2080 $  ANDA   #$40       MASK OFF ALL BUT FAULT BIT
00210   2090 $  LDB    FPWR2
00211   2100 $  CMPD   #$0
00212   2110 $  BEQ    CHGM2      OK; FOR DISABLED STATE
00213   2120 $  CMPD   #$4000
00214   2130 $  BGT    CHGM2      OK; FOR ENABLED STATE
00215   2140
00216   2150            FFLT=ERRCHG                   ! SET "CHARGER" ERROR CODE
00217   2160            GO TO CHGOFF                  ! DISABLE CHARGER AND RETURN
00218   2170
00219   2180
00220   2190 CHGM2:
00221   2200
00222   2210 /*   TEST FOR ABNORMAL CONDITIONS AND FLAG FAULTS   */
00223   2220
00224   2230        IF  VBAT < VMIN THEN          ! IS BATTERY BELOW MIN VALUE?
00225   2240          DO
00226   2250            FFLT = ERRBLO             ! YES, SET "BATTERY LOW" ERROR CO
00227   2260            GO TO CHGOFF
00228   2270          END
00229   2280
00230   2290        IF  VBAT > VMAX  THEN          ! IS BATTERY ABOVE MAX VALUE
00231   2300          DO
00232   2310            FFLT = ERRBHI             ! YES, SET "BATTERY HIGH" ERROR C
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00233    2320            GO TO CHGOFF
00234    2330          END
00235    2340
00236    2350
00237    2360
00238    2370 /*   TEST FOR LOW VOLTAGE CHARGER OPERATION & LIMIT PERFORMANCE
00239    2380
00240    2390        IF  VBAT < VLOW THEN          !  LOW VOLTAGE MODE?
00241    2400          DO                          ! YES
00242    2410            IF(FPWR=1)AND(VBAT<VLOW-VHYS2)THEN !WAS IT IN NORMAL MOI
00243    2420              DO                      ! YES
00244    2430                FFLT=ERRBOP           ! SET "BATTERY OPEN" ERROR CODE
00245    2440                GO TO CHGOFF
00246    2450              END
00247    2460
00248    2470            ELSE                      ! NO
00249    2480              DO
00250    2490                ILIM=ILOW             ! CONTROL TO LOW CURRENT LIMIT
00251    2500
00252    2510                IF CHGTIM > FTIM1 THEN ! LOW VOLTAGE OPERATION TOO
00253    2520                  DO                  ! YES
00254    2530                    FFLT=ERRTF1       ! SET "TIME FAULT #1"ERROR COD
00255    2540                    GO TO CHGOFF
00256    2550                  END
00257    2560
00258    2570                ELSE GO TO CHGM3
00259    2580              END
00260    2590          END
00261    2600        ELSE
00262    2610          DO
00263    2620               FPWR=1               ! SET NORMAL OPERATION
00264    2630
00265    2640
00266    2650
00267    2660 /*           TABLE LOOK-UP FOR NORMAL CURRENT LIMIT     */
00268    2670
00269    2680              IF(FPIN & $07=0)OR(FPIN & $07>4) THEN
00270    2690                DO
00271    2700                  FFLT=ERRSW3         ! INVALID SWITCH SETTING
00272    2710                  GO TO CHGOFF        ! DISABLE CHARGER
00273    2720                END
00274    2730              PTR= ADDR(TBLAMP)+((FPIN&$07-1)%1)! INDEX TO PROPER
00275    2740              ILIM=PTR->DATA              !SET CURRENT LIMIT
00276    2750          END
00277    2760
00278    2770
00279    2780 CHGM3.
00280    2790
00281    2800 /*     TEST FOR CHARGE TIME FAULT     */
00282    2810
00283    2820        IF (VBAT<VLIM-VHYS2) AND (CHGTIM>FTIM2) THEN
00284    2830          DO
00285    2840            FFLT=ERRTF2       ! SET FAULT TIME #2 ERROR CODE
00286    2850            GO TO CHGOFF      ! DISABLE POWER STAGE AND RETURN
00287    2860          END
00288    2870
00289    2880
00290    2890
```

```
00291    2900 /*   DEFER EQUALIZE CYCLE BY OPERATOR REQUEST   */
00292    2910
00293    2920        IF FEQU <= -1  THEN          ! ALGORITHM REQUESTS EQUALIZE CYCL
00294    2930          DO                         ! CHECK FOR OPERATOR DEFERAL
00295    2940 $  LDD FPIN                 IS SW2 DEPRESSED?
00296    2950 $  BPL CHGCTL                NO
00297    2960 $  BITB #$80                 JUST DEPRESSED?
00298    2970 $  BEQ CHGCTL                NO
00299    2980 $  COM FEQU+1                TOGGLE EQUALIZE STATUS
00300    2990          END
00301    3000        ELSE   FEQU=0                ! INSURE VALID EQUALIZE FLAG
00302    3010
00303    3020
00304    3030
00305    3040 /*     DELAY  INITIAL  CHARGER TURN-ON
00306    3050        IF POWER STAGE OFF AND DELAY SEQUENCE NOT ALREADY STARTED */
00307    3060
00308    3070 CHGCTL
00309    3080          IF (CCOUT>=0) AND (FCHGL>=0) THEN ! START DELAY?
00310    3090            DO                        ! YES
00311    3100              CHGTIM=0                ! INITIALIZE CHARGE TIMER
00312    3110              FCHGL=-1                ! FLASH CHARGE INDICATOR
00313    3120              DCOUNT=0                ! INITIALIZE DELAY COUNTER
00314    3130            END
00315    3140
00316    3150          IF  DCOUNT > 75  THEN ! DELAY COMPLETE?
00317    3160            DO                        ! YES
00318    3170              CCOUT=$80               ! ENABLE POWER STAGE
00319    3180              FCHGL=1                 ! TURN CHARGE LIGHT ON
00320    3190              FCHGS=1                 ! SET CHARGER STATUS
00321    3200              FPWR2=1                 ! FLAG ENABLED CONDITION
00322    3210              DCOUNT=0                ! RESET DELAY COUNTER
00323    3220            END
00324    3230
00325    3240
00326    3250
00327    3260 /*     CONTROL SETPOINT UPDATE ONCE EVERY 4TH CYCLE */
00328    3270
00329    3280          IF (DCOUNT>4) AND (CCOUT<0) THEN ! 4TH CYCLE?
00330    3290            DO        ! YES
00331    3300
00332    3310              IF ((VBAT>VLIM) OR (ILINE>ILIM)) AND (CCOUT>$80)
00333    3320                 THEN CCOUT=CCOUT-1 ! DECREMENT CONTROL SETPOINT
00334    3330              ELSE
00335    3340                DO
00336    3350                  IF (VBAT<VLIM-VHYS) AND (ILINE<ILIM-IHYS) AND
00337    3360                     (CCOUT<$FF) THEN CCOUT=CCOUT+1 ! INCREMENT SETP(
00338    3370                END
00339    3380
00340    3390                 DCOUNT=0                    !RESET CYCLE COUNT
00341    3400            END
00342    3410
00343    3420          DCOUNT=DCOUNT+1                 ! ADVANCE DELAY COUNTER
00344    3430          GO TO CHGEND                    ! RETURN
00345    3440
00346    3450
00347    3460 CHGOFF:      FCHGS=0           ! SET CHARGER STATUS
00348    3470              FCHGL=0           ! TURN OFF CHARGE INDICATOR
```

```
00349    3480                CCOUT=0          ! DISABLE POWER STAGE
00350    3490
00351    3500
00352    3510 CHGEND: RETURN
00353    3520 END
```

```
00001    0010          NAM     VECTOR
00002    0020          OPT     REL,CRE,P=50,G,LLE=120
00003    0030          TTL     -***-     VECTOR TABLE BCSCI
00004    0040 *
00005    0050 *        11/5/82 ASSEMELY DATE : J.R.M
00006    0060 *
00007    0070 *        DISK #200 (BACKUP : #210)
00008    0080 *        VECTOR.SA  SOURCE FILE
00009    0090 *        VECTOR.RO  OBJECT FILE
00010    0100 *
00011    0110          XREF    INIT,FIRQ,IRQ
00012    0120 **
00013    0130 **     INTERRUPT VECTOR STORAGE
00014    0140 **
00015    0150          ASCT
00016    0160          ORG     $FFF2
00017    0170 *
00018    0180          FDB     INIT      SWI3 VECTOR (UNUSED)
00019    0190          FDB     INIT      SWI2 VECTOR (UNUSED)
00020    0200          FDB     FIRQ      FAST INTERRUPT VECTOR (TIMER 1/SEC)
00021    0210          FDB     IRQ       NORMAL INTERRUPT VECTOR (EOC -ADC)
00022    0220          FDB     INIT      SWI VECTOR (TRAP RESTART)
00023    0230          FDB     INIT      NMI VECTOR (UNUSED)
00024    0240          FDB     INIT      RESTART VECTOR (POWER-UP & WATCH-DOG)
00025    0250          END
```

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```
00001    C       ZRQQ1                   Motorola-6809                   ndh:27-Sep-82
00002    C
00003    C Written by -          Neil D. Herbert                 09-Sep-82
00004    C                  GLEER Computer & Software Systems
00005    C                  Gould, Inc., Rolling Meadows, Ill.
00006    C                  312/640-4472
00007    C
00008    C Modifications:
00009    C       Corrections from J. Mezera.
00010    C               Neil D. Herbert                 13-Sep-82       ndh-010
00011    C
00012    C       Edited for Motorola-6809.
00013    C               Neil D. Herbert                 27-Sep-82       ndh-020
00014    C
00015    C       ********************************************************************
00016    C               Impedance Calculation           Ver 2.0
00017    C       ********************************************************************
00018    C
00019    C Description:
00020    C       Calculates battery impedance from internal resistance,
00021    C       capacity, & state of charge.
00022    C
00023    C Inputs:       Battery internal resistance, capacity,
00024    C               & state of charge.
00025    C
00026    C Outputs:      Battery impedance.
00027    C
00028    C Subprograms called:       (none)
00029    C
00030    C
00031    C
00032           FUNCTION ZRQQ1(R2,Q2,Q)
00033    $H    ZRQQ1
00034    C
00035    C Arguments:        R2      = Internal resistance
00036    C                   Q2      = Battery capacity
00037    C                   Q       = State of charge
00038    C
00039    C
00040    C Declarations.
00041    C
00042    C
00043    C
00044    C Main Body.
00045    C
00046           Q1=Q
00047           IF(0.999*Q2.GT.Q1)  Q1=0.999*Q2 ;limit denominator ;ndh-01
00048           ZRQQ1=R2*Q2/(Q2-Q1)
00049           RETURN
00050           END
```

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